AN APOLLO SYSTEM DESCRIPTION

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DRAFT

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FOREWORD

The Moon is a satellite of the Earth, revolving about the Earth in an elliptical orbit from west to east every 27 days, 7 hours and 43 minutes. Gravitational stabilization causes the Moon to rotate about its axis with the same period that it revolves about the Earth. Thus the Moon always presents its same side toward the Earth. The Moon's distance from Earth varies from 221,463 miles at perigee to 252,710 miles at apogee. The mean distance is 238,857 miles.

The Moon is 2,160 miles in diameter. Its mass is about one-eightieth that of the Earth and its volume one-fortyninth. The area of the Moon is about one-fourth the surface of the Earth, and its circumference is about 6,800 miles. The Moon has no atmosphere ($< 10^{-10}$ mm Hg). The temperature of its surface varies from about -170°C to +115°C for areas which receive sunlight at some time during the course of a lunar day-night cycle.

The surface of the Moon is topographically as variable as that of the Earth. We can observe valleys, basins, faults, scarps, ridges, hills, mountain ranges, etc. Some of its peaks reach 20,000 feet in height. Superimposed on these features are a multitude of circular and semicircular craters of varying dimensions ($\sim$30,000 on the earthward side), probably caused over long periods of time by the impacts of meteors.

Early day astronomers thought that certain dark areas of the Moon were covered with water and named them seas and oceans. Actually, the Moon is as devoid of surface water as it is of an atmosphere. Most astronomers believe that it is covered by a thin layer of dust.

From the scientific standpoint, exploration of the Moon is of great importance. Having neither wind nor surface water, the Moon's surface may have preserved most of the record of its development. Thus, the Moon offers an opportunity to study in some detail the evolution of a planetary body since its birth. Such study may help answer some of the key questions of science - how was the solar system created; how did it develop; how did life originate?

1. INTRODUCTION

The specific objective of Project Apollo is to land two astronauts and scientific equipment on the surface of the Moon for the purpose of manned exploration of the lunar surface. This report, which has been compiled from current literature, provides a condensed description of the major items in the Apollo program. Topics include a description of the Apollo space vehicle and its mission, along with a description of the supporting ground facilities. The development program leading to the manned lunar landing mission and the relationship of Apollo to other space programs are also briefly discussed.

2. MISSION PROFILE

The manned lunar landing mission will utilize the Lunar Orbit Rendezvous mode employing the Apollo spacecraft and the Saturn V launch vehicle as shown in Figure 2-1. The three-stage launch vehicle consisting of the S-IC, S-II, and S-IVB stages and an Instrument Unit will be used to place the spacecraft into an Earth parking orbit. A second burn of the S-IVB will inject the spacecraft into a translunar trajectory.

The Apollo spacecraft, which will accommodate the three-man crew for the mission, consists of a Command Module (CM), a Service Module (SM), a Lunar Excursion Module (LEM), an Adapter and a Launch Escape System (LES). The CM will serve as the in-flight command center throughout the mission and as the reentry vehicle during the terminal phase. The SM will provide all spacecraft propulsion and reaction control needs from separation of the S-IVB until SM separation prior to reentry into the Earth's atmosphere except for LEM separation, landing and return to lunar orbit. The LEM, which consists of a descent stage and an ascent stage, will provide a means for transferring two crew members from the lunar orbiting Command and Service Modules (CSM) to the lunar surface and for effecting a rendezvous with the CSM upon completion of the lunar exploration. The Adapter is the structural element containing the LEM and connecting the spacecraft to the launch vehicle from launch through injection into the translunar trajectory. The Launch Escape System (LES), while affixed to the CM, will provide a means for emergency separation of the CM from the space vehicle during the initial phases of Earth launch.

The Apollo Saturn V will be launched from Complex 39 at the Merritt Island Launch Area (MILA) which is adjacent to Cape Kennedy. Launch azimuth will be between 72° and 108°. Figure 2-2 depicts the launch profile

At ignition, the five F-1 engines of the S-IC first stage will start to generate up to 7,500,000 pounds of thrust. When the engines have reached sufficient thrust, the hold-down arms will release and the 6,000,000 pound vehicle will lift off. Open-loop guidance (pitch programmer) will be employed during S-IC burn. Approximately 2-1/2 minutes after ignition and upon propellant depletion (at an altitude of about 35 nautical miles and a velocity of 7,770 fps relative to the Earth), the engines will cut off and the first stage will separate.

Upon ignition of the S-II second stage, its five J-2 engines will provide 1,000,000 pounds of thrust. Guidance information for the S-II burn will be derived from the on-board guidance system located in the Instrument Unit. When the S-II propellant tanks are empty, about 6-1/2 minutes after ignition and at an altitude of 100 nautical miles and a velocity of 21,000 fps, the second stage will be separated and will fall away.

Next, the S-IVB third stage will ignite, its single J-2 engine providing 200,000 pounds of thrust. The third stage will burn part of its fuel for about 2-3/4 minutes until the spacecraft and the Saturn S-IVB stage are in a parking orbit about the Earth. Space vehicle attitude stabilization during this orbit phase will be provided by the S-IVB stabilization control system.

While the vehicle is in Earth orbit, the spacecraft and the S-IVB stage will be checked out by the astronauts and, through telemetry, by the Integrated Mission Control Center (IMCC) at Houston. The vehicle will orbit the Earth at 100 nautical miles for no more than three orbits. If all systems are functioning properly, the S-IVB stage will be ignited again at the appropriate point in Earth orbit to begin the journey to the Moon some 237,100 ± 15,600 statute miles away. After a little over five minutes of S-IVB burn, the spacecraft will reach the required escape velocity of about 36,800 fps for the translunar trip. Gravitational attraction of the Earth slows the spacecraft down as its separation increases; thus the average velocity of the spacecraft for the translunar flight will be about 4,800 fps with respect to the Earth.

After the S-IVB second burn has ended, transpositioning of the LEM will occur. This is depicted in Figure 2-3. First, the forward Adapter will be jettisoned. Next, the CM and the SM will separate from the LEM/S-IVB leaving the LEM attached to the S-IVB. Using the reaction control system aboard the SM, the astronauts will turn the CSM around and dock nose-to-nose with the LEM/S-IVB. Finally, when the structural connection has been accomplished, the S-IVB and the remainder of the Adapter will be separated.

During the approximately 72 hours of translunar flight, the astronauts with ground support will make any necessary mid-course corrections to the flight path by firing either the main

SM propulsion engine or the SM reaction control engines. The translunar trajectory is expected to be of the free return type. Thus, if an emergency should occur prior to retrofire for lunar orbit insertion, the spacecraft will be capable of returning within the vertical reentry corridor with only the application of propulsive impulses from the SM reaction control system.

As the spacecraft encounters the local gravitational attraction of the Moon, its velocity with respect to the Moon will increase. Thus, to place the spacecraft in a lunar orbit, the astronauts must execute a retrofire maneuver. This will consist of orienting the spacecraft and igniting the 22,000 pound thrust SM engine to slow the spacecraft enough to place it in a circular lunar orbit about 80 nautical miles above the Moon's surface.

Two of the astronauts will then climb through the hatch from the CSM and enter the LEM as shown in Figure 2-4. They will proceed to perform a complete checkout of the LEM to ensure that all systems will function properly. The LEM will then be detached from the CSM and its 10,500 pound thrust descent engine will be ignited to provide thrust for about half a minute. This impulse will place the LEM in an elliptical-descent transfer orbit with a perilune* of 50,000 feet as shown in Figure 2-5. From this lower altitude the astronauts can visually observe the conditions at the landing site.

Several sites are under consideration for the initial lunar landing. It is expected that the preselected LEM landing site will be within a latitude belt extending about 5° on either side of the lunar equator. The longitude restriction will be determined from temperature, lighting, and other considerations on the near-Earth side of the Moon.

When the LEM reaches the minimum altitude of its approach orbit, it will be traveling at a speed of about 5,600 fps with respect to the lunar surface. At this time, the landing stage engine will be ignited again to slow the LEM and cause it to descend to the surface. As the LEM slows and falls towards the lunar surface, the engine will be throttled down gradually until the craft reaches a hovering (zero component for the vertical velocity) position about 500 feet above the surface and from which

*Perilune - the point in an elliptical orbit about the Moon at which an orbiting vehicle is closest to the Moon. Periselene and pericynthion are also frequently used.

it will descend to the most acceptable landing point within a 1,000 foot radius. The craft will land at a horizontal speed of less than ten fps and a vertical speed of less than five fps.

During the touchdown maneuver, the CSM will always be within line of sight of the LEM. At any point up to and including the hover maneuver, the astronauts can, if necessary, ascend and get back to a rendezvous with the CSM during the first orbit. At touchdown, the CSM will be nearly directly overhead.

The LEM will carry about 215 pounds of scientific equipment to the lunar surface and will be capable of returning a total of 80 pounds of equipment and lunar samples to the CSM. While on the lunar surface, the two explorers will first check out the LEM in preparation for the return flight. After that, one of the two astronauts will leave the LEM and explore the lunar surface for a period of up to four hours. He will be capable of maintaining voice communication with the astronaut in the LEM for distances up to five nautical miles. Using the LEM communication system as a relay station, he will also be capable of voice communication with the Earth and with the lunar orbiting CSM. The nominal stay-time on the lunar surface for the initial landing will be 24 hours.

Upon completion of their lunar surface mission, the two LEM explorers will begin the countdown for launch. The ascent stage of the LEM will separate from the descent stage and lift off. The 3,500 pound thrust ascent engine will burn for about six minutes until the craft reaches orbital speed of about 5,600 fps at the perilune of 50,000 feet. One of the rendezvous trajectories now under study utilizes the Hohmann transfer ellipse. In this trajectory, the LEM would proceed towards rendezvous on a coplanar path, that is, at one point, tangent to the lunar orbit of the CSM.

During powered flight and the coast phase that follows, radars aboard the CSM and the LEM will track each other. Ordinarily, the LEM engine will make any course corrections needed to assure the rendezvous, but if an emergency occurs, the CSM will effect rendezvous.

Rendezvous is expected to occur behind the Moon. The LEM guidance system will bring the LEM within a few hundred feet of the CSM at which point the docking maneuver will be completed by the astronauts.

Once the explorers have climbed back aboard the CSM, it is expected that the LEM will be detached and left in lunar orbit. The SM main propulsion engine will then be ignited for about 2-1/2 minutes to provide the additional velocity of 2,900 fps needed to escape the gravitational attraction of the Moon in a transearth trajectory. During return, the SM engines will be employed to make mid-course corrections as required.

After the final flight path adjustments have been completed to assure hitting the vertical reentry corridor* (as determined by skip-out, heating and crew stress considerations), the SM will be discarded and the CM will be oriented for reentry. During reentry, the offset center of gravity of the CM will provide a lift-to-drag ratio of approximately 0.5. Combined with the roll capability of the CM, this will permit maneuvering of the CM through part of its descent through the atmosphere.

After the main aerodynamic deceleration has slowed the CM to below the speed of sound, three parachutes will be deployed as shown in Figure 2-6, and the CM will float gently to rest on the Earth's surface. A water landing site is considered most probable.

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* Reentry Corridor - that region of the altitude-velocity plane where continuous flight is possible because the dynamic pressure is great enough to support lifting flight, and yet the heating rates are low enough to allow sufficient surface cooling. The nominal operational reentry corridor for the manned CM will be 40 miles.

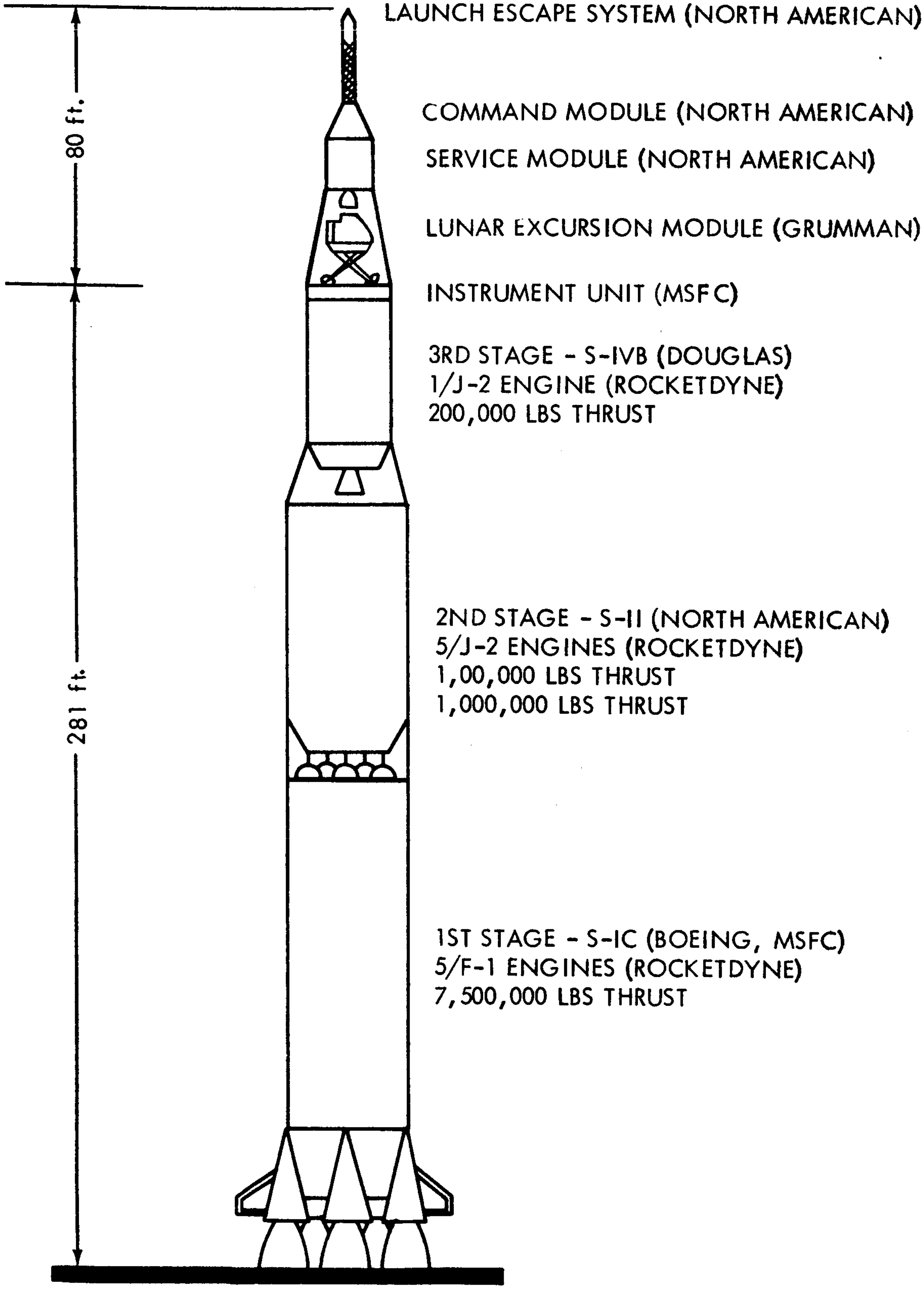

FIGURE 2-1 APOLLO/SATURN V SPACE VEHICLE

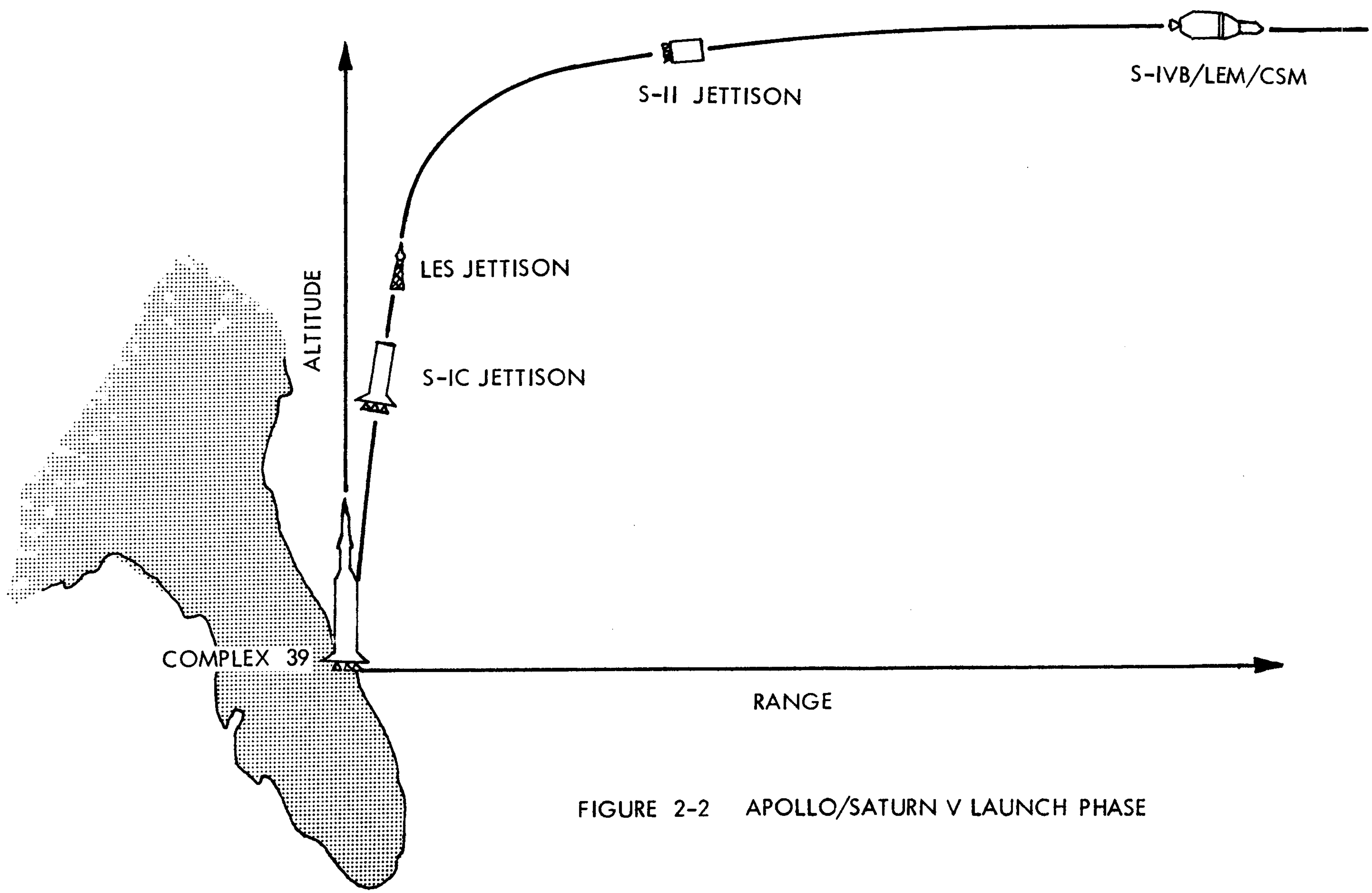

FIGURE 2-2 APOLLO/SATURN V LAUNCH PHASE

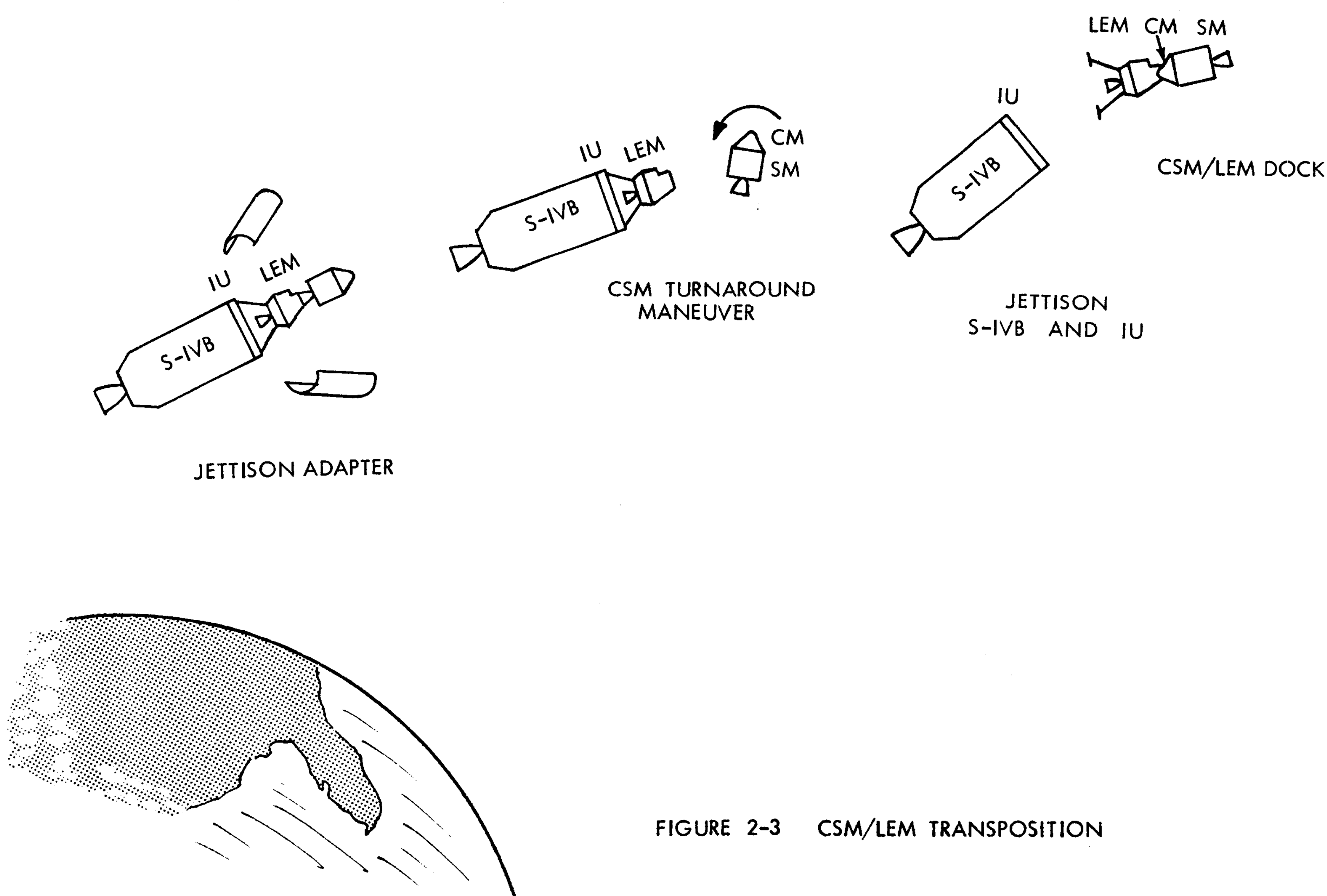

FIGURE 2-3 CSM/LEM TRANSPOSITION

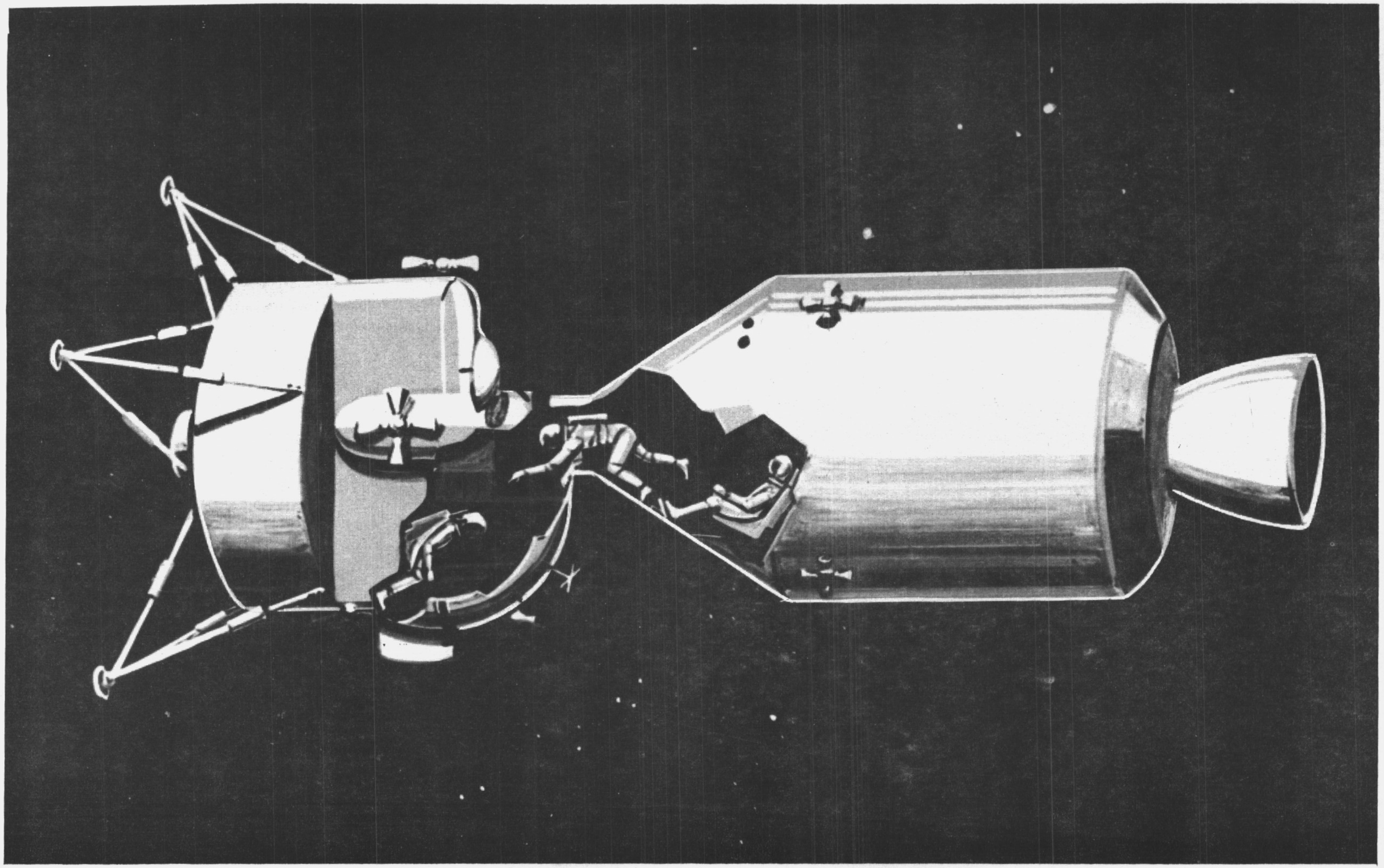

FIGURE 2-4   TRANSFER OF ASTRONAUTS TO LEM

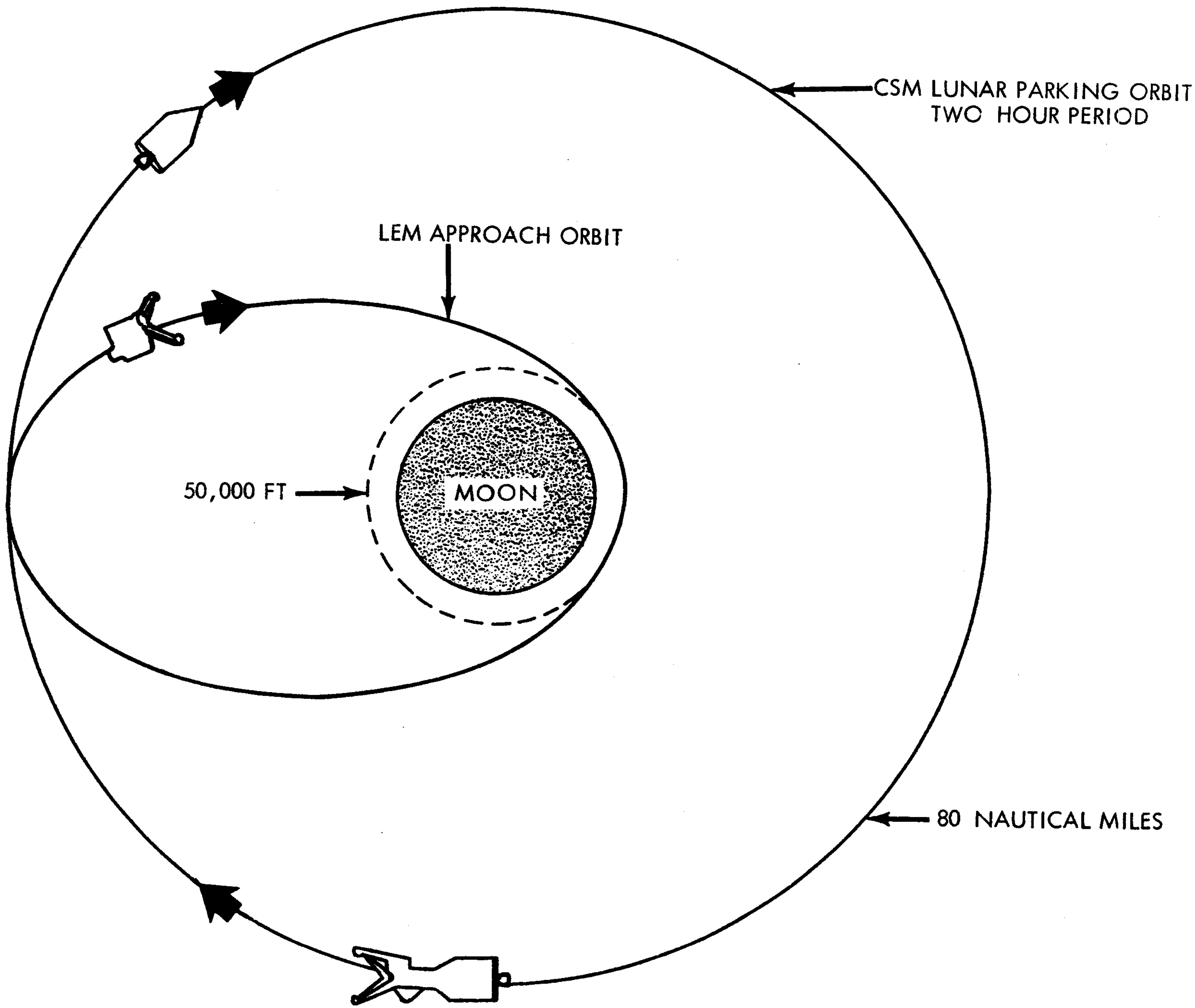

FIGURE 2-5 ILLUSTRATIVE LUNAR APPROACH ORBIT

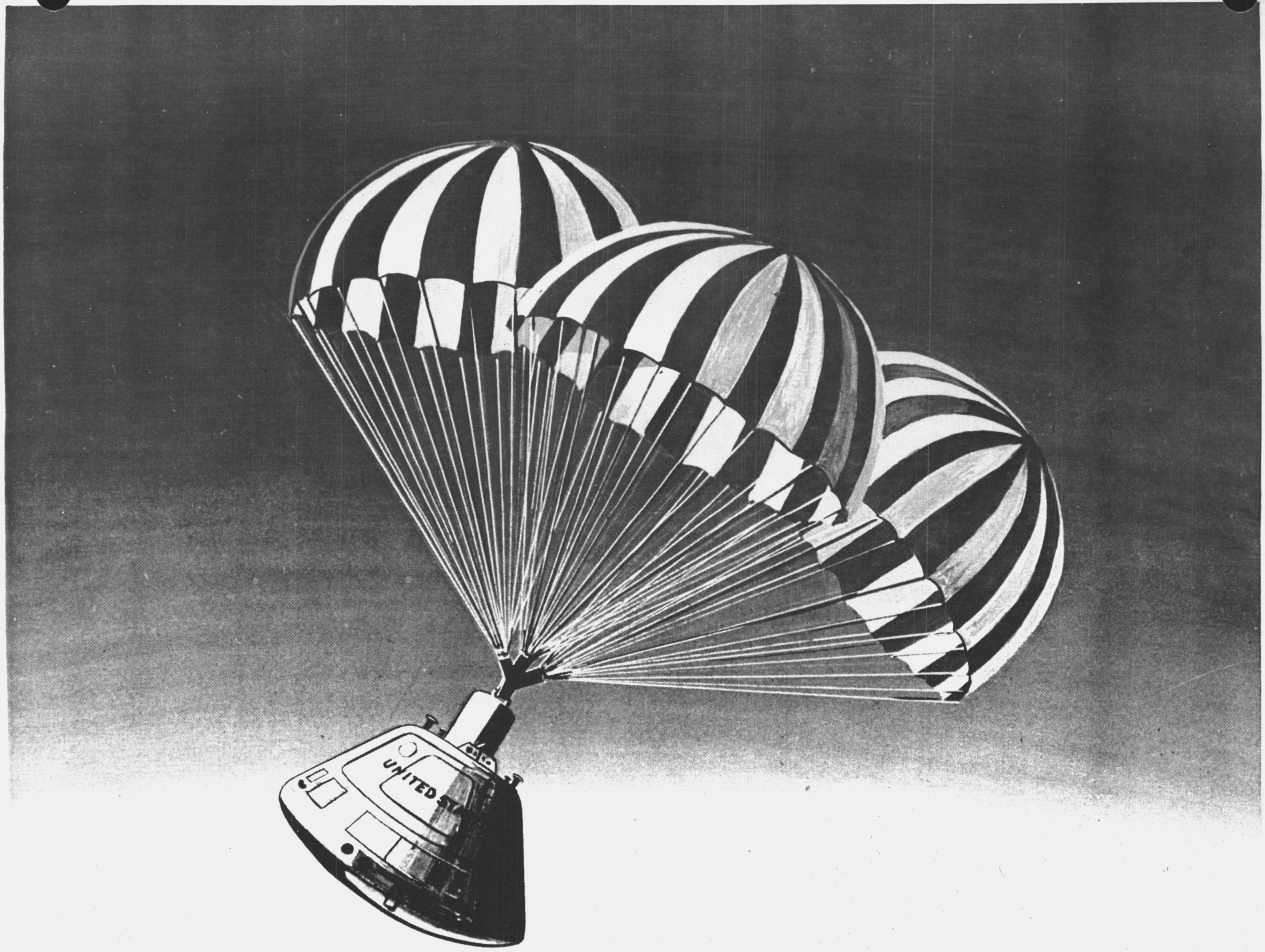

FIGURE 2-6 TERMINAL DESCENT TO EARTH

3. SATURN V DESCRIPTION

The Saturn V, shown in Figure 2-1, is a three stage launch vehicle which will be used to place the Apollo spacecraft into an Earth parking orbit and then into a translunar trajectory. The Saturn V consists of the S-IC first stage, the S-II second stage, the S-IVB third stage, and an Instrument Unit. Approximate weights, dimensions, and capabilities of the Saturn V are:

Lift off weight	6,000,000 pounds
Length	281 feet
Diameter	33 feet
Payload in low earth orbit	240,000 pounds
Payload into a lunar transfer trajectory	90,000 pounds

Saturn V First Stage (S-IC)

The first stage of the Saturn V launch vehicle will be the S-IC, shown in Figure 3-1. This stage will propel the launch vehicle and the Apollo spacecraft for approximately the first two and one-half minutes of the flight. Nominal dimensions, approximate weights and the thrust of the S-IC are:

Diameter	33 feet
Length	138 feet
Dry weight	300,000 pounds
Fueled weight	4,600,000 pounds
Thrust	7,500,000 pounds

Propulsion for this stage is a cluster of five F-1 liquid rocket engines which develop a nominal sea level thrust of 1,500,000 pounds each. The propellants for the F-1 engines are liquid oxygen and RP-1, a kerosene fuel. These propellants are pumped by a direct drive centrifugal pump, driven by a gas generator, into the combustion chamber at high pressure. Vehicle control and stability are obtained by directing the thrust of the four out-board engines in response to signals from the control system which is housed in the Instrument Unit.

Propellants for the F-1 engines are contained in two containers connected by an intertank section. The liquid oxygen tank is positioned above the fuel tank. The containers are cylindrical with ellipsoidal bulkheads and are supported by frames and longitudinal stiffeners. The S-IC is designed to provide a structure which will be self-supporting, without depending upon pressurization of its propellant containers. Four fins are located out-board on the structure of the stage near the engines to provide added aerodynamic stability.

Termination of the S-IC stage burning occurs upon depletion of the propellant supply in either of the propellant tanks. Separation is assured by firing solid propellant retro-rocket motors located in the engine skirts of the S-IC stage.

Saturn V Second Stage (S-II)

The S-II stage, shown in Figure 3-2, is designed to propel the vehicle and spacecraft from an altitude of 200,000 feet to approximately 600,000 feet. Nominal data on this stage are presented in the table below:

Diameter	33 feet
Length	81 feet
Dry weight	80,000 pounds
Fueled weight	1,015,000 pounds
Thrust	1,000,000 pounds

S-II propulsion is provided by a cluster of five J-2 liquid rocket engines, each of which develops a nominal vacuum thrust of 200,000 pounds. The liquid oxygen and liquid hydrogen propellants used in the J-2 are pumped from the tanks into the combustion chamber by gas generator-driven pumps. These propellants are contained in two tanks with ellipsodial bulkheads. Liquid hydrogen, which has a density of about 1/16 that of liquid oxygen, is located in a tank forward of the liquid oxygen tank. The stage is designed to provide a structure which will be self-supporting without pressurization of the propellant tanks. Vehicle control and stability are obtained by directing the thrust of the four out-board engines in response to signals from the control system located in the Instrument Unit.

Termination of the S-II stage burning occurs upon depletion of the propellant supply in either of the propellant tanks. A propellant utilization system is provided to minimize the amount of residual propellant

Four solid propellant rocket motors are used in the S-II stage to provide acceleration to settle the propellants to the bottom of the tanks after separation of the S-IC and prior to second stage ignition.

Separation of the S-II is assured by four solid propellant rocket motors located in the interstage structure forward of the liquid hydrogen tank to provide retro thrust.

Saturn V Third Stage (S-IVB)

The S-IVB stage, shown in Figure 3-3, is designed to insert the spacecraft into an Earth parking orbit and to inject the spacecraft into a translunar trajectory. Some nominal data on the S-IVB stage are listed below:

Diameter	22 feet
Length	59 feet
Dry Weight	22,000 pounds
Fueled weight	258,000 pounds
Thrust	200,000 pounds

Propulsion is supplied by a single J-2 engine developing a nominal vacuum thrust of 200,000 pounds. As in the second stage, this J-2 burns liquid oxygen and liquid hydrogen supplied from the propellant tanks by gas generator driven pumps. Vehicle pitch and yaw control are achieved by gimbaling the engine. Control signals are developed in the guidance and control system in the Instrument Unit.

An auxiliary propulsion system, shown in Figure 3-4, is located at two points, 180° apart, on the aft end of the main stage structure. Three engines for attitude and roll control, and two engines for propellant settling are located at each position. Propellant tanks for this system are equipped with positive expulsion devices. Propellants for this system are 50% unsymmetrical dimethylhydrazine (UDMH) and 50% hydrazine (N_2H_4) (by weight) and nitrogen tetroxide (N_2O_4). This combination is earth storable and hypergolic. The six attitude control engines have a thrust of 150 pounds each. Two of the four ullage engines have a thrust of 150 pounds and are used during the LH_2 venting cycle. The other two ullage engines have a thrust of 1,750 pounds and are used prior to J-2 ignition.

The main propellant tanks are designed to provide a structure which is self-supporting without depending upon pressurization of the tanks. The propellant containers are positioned with the liquid hydrogen tank forward of the liquid oxygen and are separated by a common bulkhead.

Saturn V Instrument Unit

Forward of the S-IVB propellant tanks is a module which is cylindrical in shape and is identified as the Instrument Unit. It is three feet in length and 22 feet in diameter.

The Instrument Unit houses the guidance system, telemetering equipment, power supply batteries, inverters, and cooling equipment.

The powered flight of the Saturn V will be directed by the launch vehicle systems. The initial phase of the flight, that powered by the S-IC stage, will be flown "open loop" in the guidance sense; that is, the steering commands are given in accordance with a pre-determined program. The following phases, those powered by the S-II and S-IVB stages, will be flown with steering commands derived from measurements and computations by the launch vehicle guidance system. Guidance during the second S-IVB burn will normally be provided by the launch vehicle guidance system, although the spacecraft system in the Command Module will also have the capability to provide guidance commands during this S-IVB burn. Cutoff of both the S-IC and S-II stages will be commanded by sensors indicating propellant depletion. Cutoff of the S-IVB will be commanded by the guidance system when it determines that the proper conditions for the desired orbit and later for the desired translunar trajectory have been obtained.

The guidance and control system in the launch vehicle is an all-inertial system which uses a digital computer for the guidance computations and analog circuits for the control functions. Acceleration measurements for the guidance and attitude measurements for the control system are obtained from the stabilized platform subsystem. This stabilized platform uses four gimbals and has three accelerometers and three gyroscopes.

The environment in some compartments of the Instrument Unit will be temperature controlled during preflight operations by a ground environmental control system. During flight, a liquid nitrogen cooler assembly will provide cooling for circulated air.

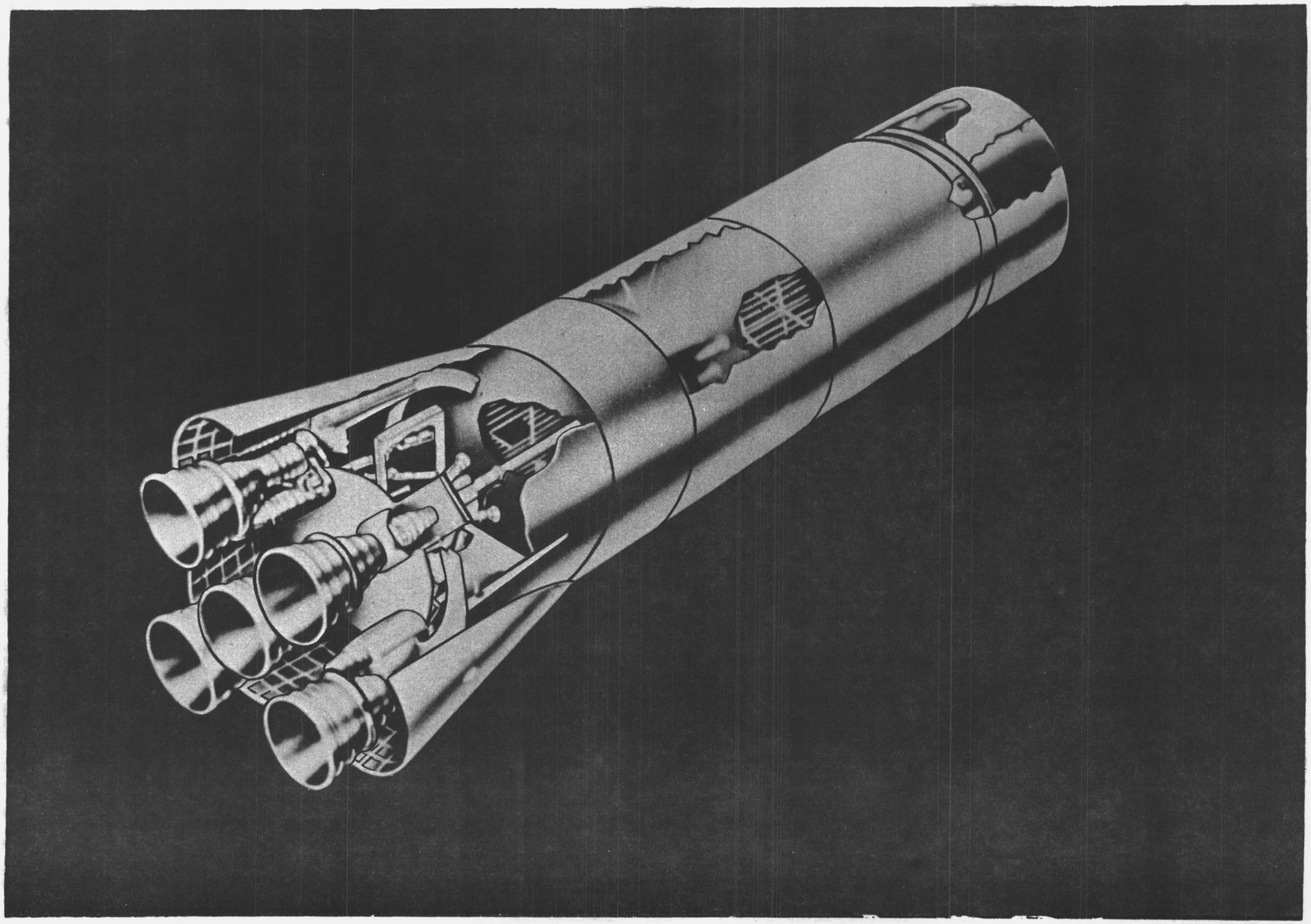

FIGURE 3-1 S-IC STAGE OF SATURN V

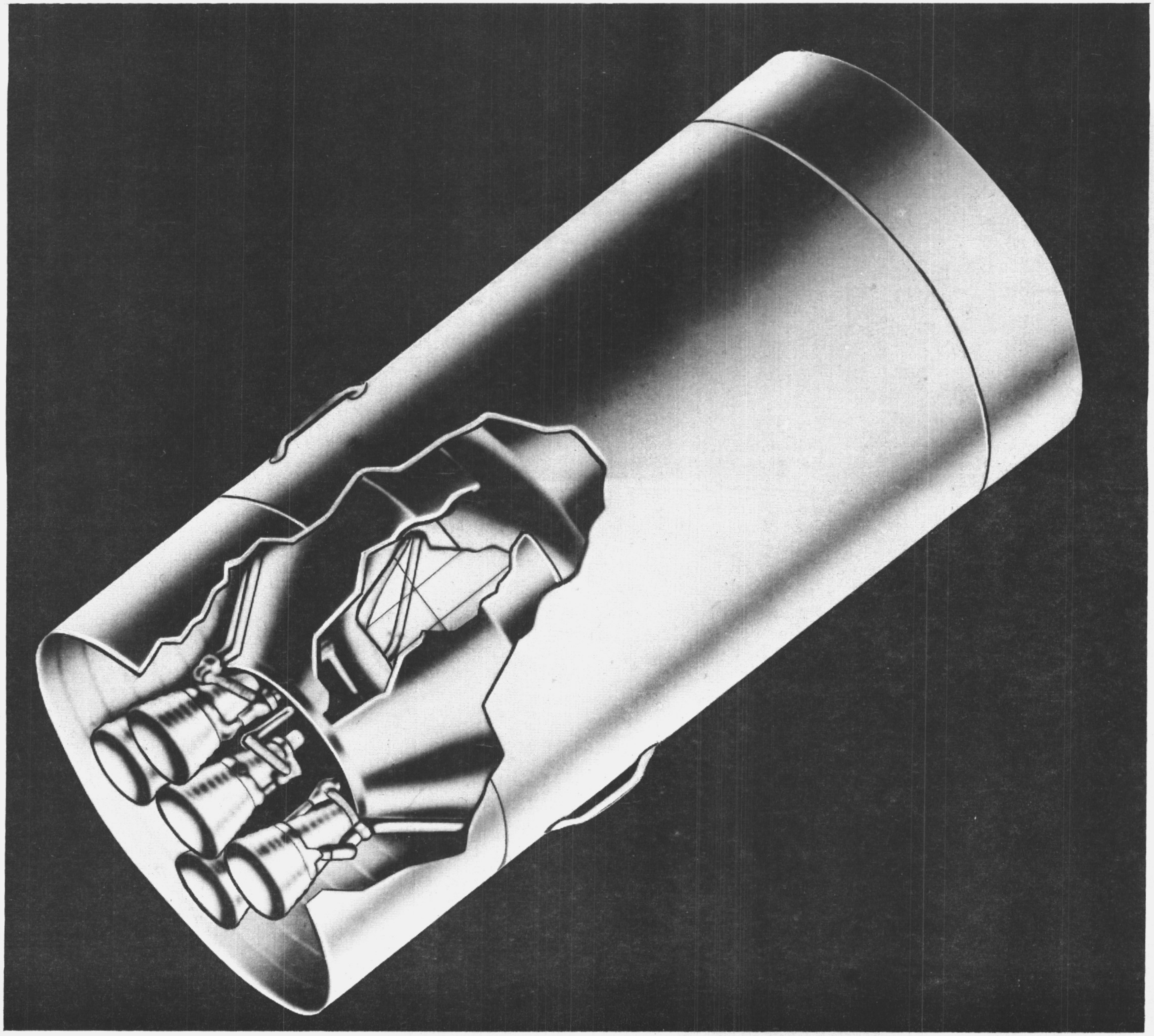

FIGURE 3-2 S -II STAGE OF SATURN V

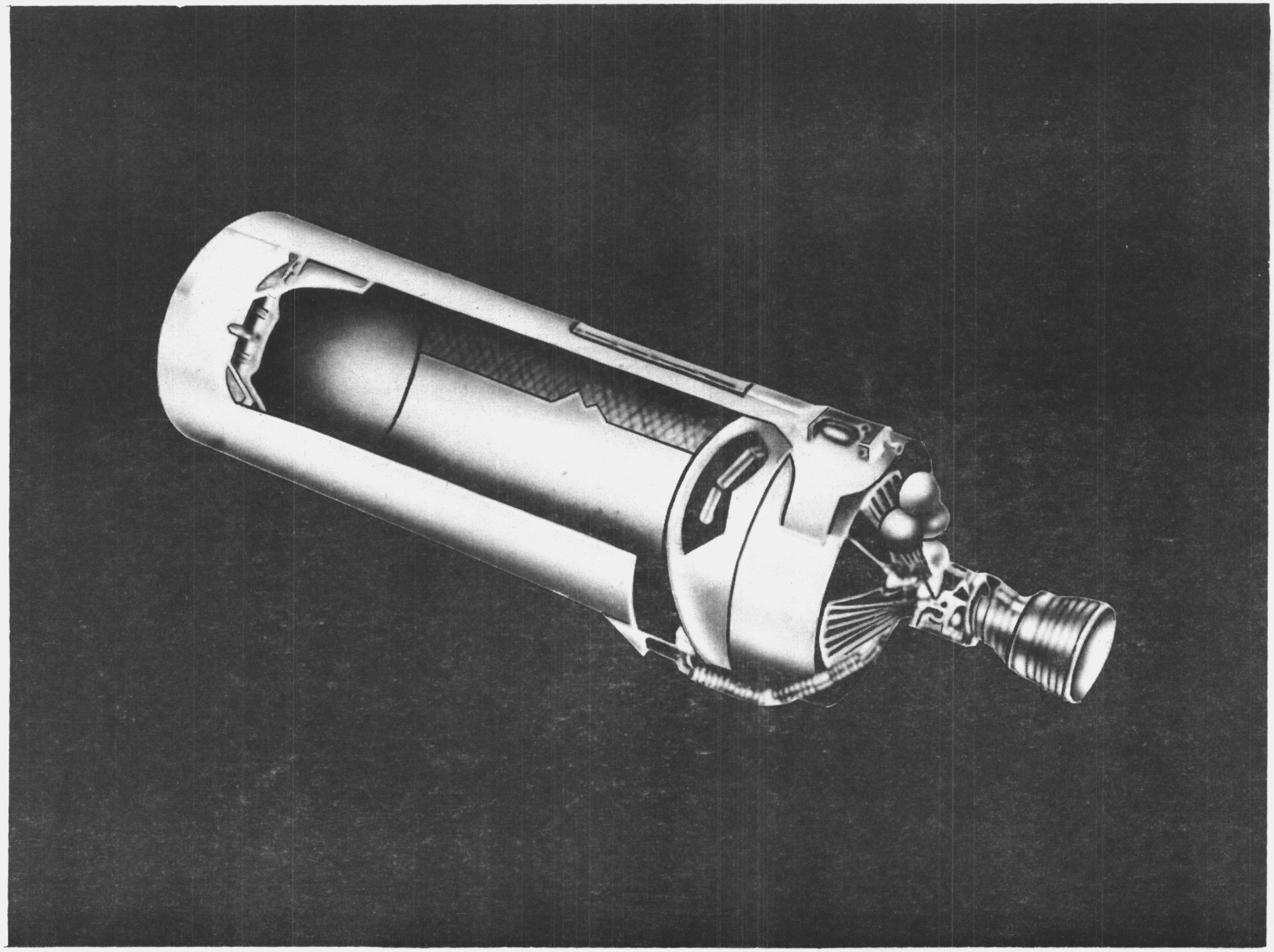

FIGURE 3-3 SATURN S-IVB STAGE

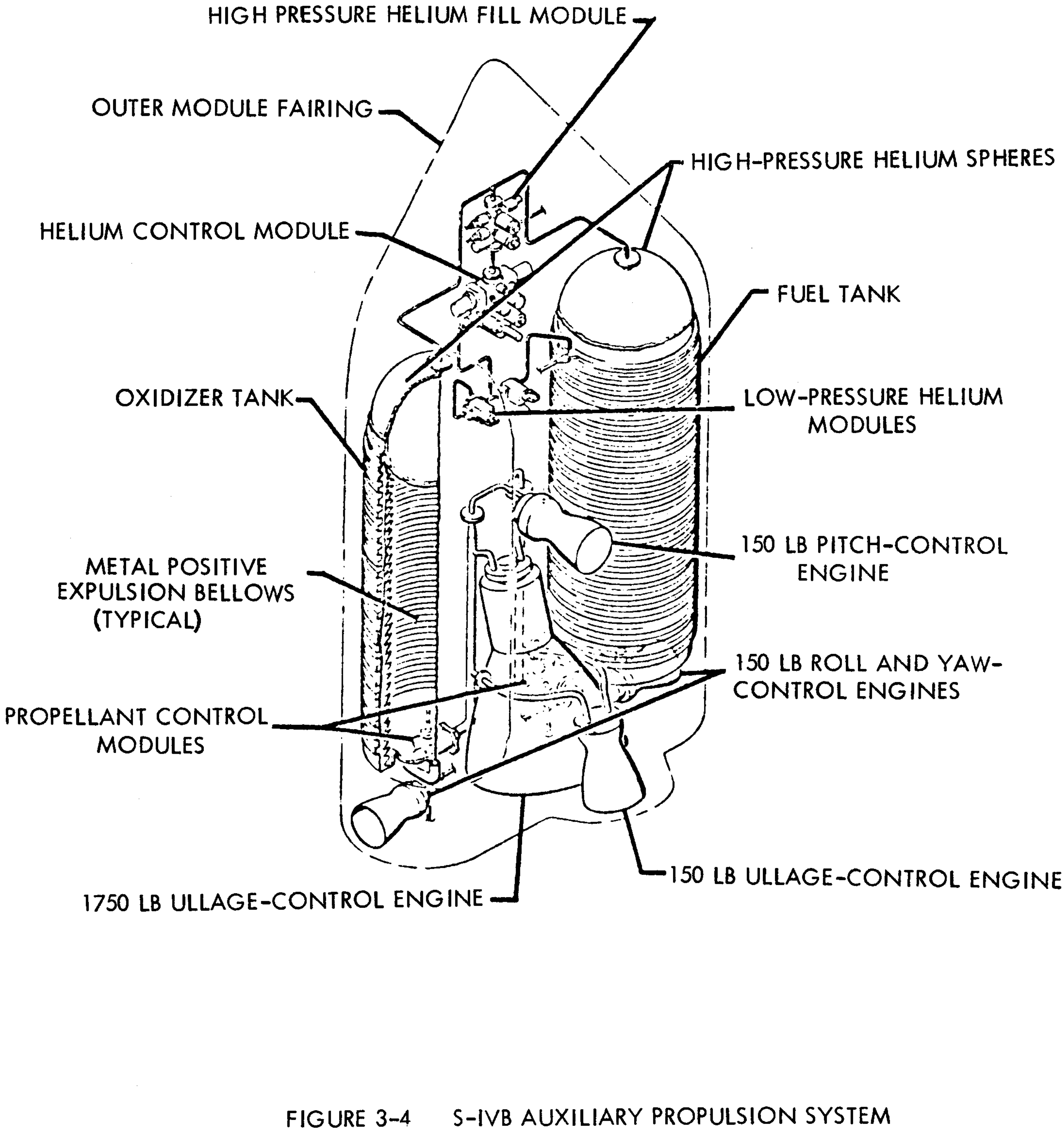

FIGURE 3-4 S-IVB AUXILIARY PROPULSION SYSTEM

4. APOLLO SPACECRAFT DESCRIPTION

The Apollo spacecraft design will utilize separate units to fulfill specific mission requirements. These units are the Command Module, the Service Module, the Lunar Excursion Module, the Launch Escape System, and the Adapter.

The spacecraft will be about 80 feet in length and will weigh approximately 96,600 pounds at liftoff.

Command Module (CM)

The Apollo Spacecraft Command Module will serve as the spacecraft command center where crew-initiated control functions will be performed. The living quarters for three men, necessary flight equipment, and a livable environment will be contained within the CM. Aids necessary to assure recovery of the crew after the Earth landing will also be provided in the CM. Some of the supporting systems will be contained in the Service Module rather than the CM and will be jettisoned before reentry; in this manner, the reentry weight of the CM is minimized.

The shape of the CM is shown in Figure 4-1. Nominal dimensions of the module are:

Height	13 feet
Diameter	13 feet
Dry weight	9,500 pounds

A lift-to-drag ratio of up to 0.5 will be provided by an offset center of gravity. This lift vector will provide control of the reentry flight path when the roll control system is used to control the direction of the vector.

The internal volume provided for the three-man crew will be approximately 300 cubic feet.

Propulsion is provided in the CM only for attitude and roll control during reentry, after the Service Module has been jettisoned. This propulsion is provided by twelve engines which are pressure fed from positive expulsion tanks supplying monomethylhydrazine (MMH) and nitrogen tetroxide (N_2O_4). These propellants are earth storable and hypergolic. Ablation-cooled thrust chambers are used with a refractory metal throat insert to provide a fixed throat diameter throughout the firing time.

An ablative type of reentry heat shield will be used on the CM. This heat shield is constructed of ablative material supported by a steel honeycomb substructure.

The main Apollo spacecraft guidance and navigation equipment will be located in the CM. The guidance and navigation subsystem will be used to determine the position, velocity, and trajectory of the spacecraft. This system is comprised of three major subsystems: the inertial measurement unit (IMU), the Apollo guidance computer (AGC), and the optical subsystem. In addition to providing guidance and navigation from translunar injection until Earth landing, the system also monitors the launch vehicle guidance system during Earth launch and Earth orbit.

Sensing elements of the system provide navigation information to the data processing elements which then provide the information and control signals to perform any stabilization and control functions required. The sensing elements include the radar, scanning telescope, sextant, and the IMU.

Operation of the IMU as the primary inertial sensing device is based on acceleration and orientation measurements obtained from accelerometers and gyroscopes. The IMU will use a three-gimbal inertial platform which will be stabilized by three gyroscopes. Three orthogonally-mounted accelerometers will be carried on the platform.

The Apollo Guidance Computer is the data processing center of the guidance and navigation system. It is a general purpose computer which keeps time, stores the reference trajectories and other data, receives information from the accelerometers in the IMU, receives angular-measurement data from the scanning telescope and sextant, receives manual inputs and commands from the astronaut, and receives angular information from the IMU. Using this information, the AGC computes position and velocity and generates commands which go to the stabilization and control system, and which can be presented on the display panel.

An optical subsystem is incorporated in the guidance and navigation system which, under the control of an astronaut, will be used to determine the position and attitude of the spacecraft and to align the IMU. A scanning telescope will be used for orbit determination and as a finder for the sextant. The scanning telescope will be a single-line-of-sight instrument incorporating low-magnification wide-field optical features. A space sextant will be used during the translunar and transearth phases of the mission. The sextant will be a dual-line-of-sight instrument incorporating high-magnification narrow-field optics and will be used for direct measurements of the angle between the line of sight to a star and a landmark or another star. The trunnion and shaft angle of the sextant and the scanning telescope are transmitted to the AGC and are displayed digitally at the AGC.

Throughout the mission, the systems on board the space vehicle will work cooperatively with Earth-based tracking and computation facilities. These facilities will have continuous information on the vehicle position and velocity which will be furnished the space vehicle in various phases of the mission as required.

Life support systems provided for the crew will be of the non-regenerative type and will supply approximately 42 man days of operation.

The Environmental Control System (ECS) supplies oxygen to the pressure suits and to the CM cabin. It controls the gas pressure to a nominal 5 psia, the temperature to 70-75°F, and the relative humidity to 40-70%. In addition to its supply and control function the ECS removes debris, CO_2 and odors from the oxygen. The ECS controls the water supply system by collecting, storing and distributing potable water from the fuel cells located in the SM and waste water not potable from the suit circuit. A water-glycol system, which is part of the ECS, provides cooling for the suit circuit, CM atmosphere, electronic equipment and the potable water. The ECS will be capable of maintaining cabin pressure at a safe level long enough for the astronauts to don their space suits should a small leak develop.

The ECS equipment is located in the CM and in the SM. Four space radiators for ejection of heat from the water-glycol circuit are located in the SM. The controls and regulators along with activated charcoal and lithium hydroxide, are positioned in the operating circuits in the CM to remove odors and CO_2 from the atmosphere. The main oxygen supply is located in the SM but a small quantity of oxygen is located in the CM for crew supply during reentry.

A one day supply of potable water will be carried aboard the CM as emergency supply. Normally, water for use during the mission will come from the fuel cells located in the SM. Food will be stored aboard the CM in the freeze dried condition to reduce weight and to eliminate the need for refrigeration. The food is reconstituted by adding a measured quantity of water to the food packets.

Personal hygiene needs will be provided for in the CM. Battery operated razors for shaving, chemically treated cloths for washing and toothbrushes with ingestible dentifrices for cleansing teeth and gums will be supplied. Body wastes will be collected and stored. Biomedical equipment will be included in the supplies.

Electrical power for operation of the CSM systems will be produced by three fuel cell modules located in the SM. An auxiliary power system of three zinc-silver oxide batteries will be located in the CM. Two of these batteries will provide power requirements during the reentry and recovery flight phases. The third battery will supply essential loads during the post-landing phase.

An Earth Landing System (ELS) is incorporated in the CM for landing on either land or water. This system consists of a forward heat shield separation mechanism, a parachute subsystem, a sequencer and recovery aids. The forward heat shield separation mechanism is gas generator operated and serves to eject the shielding at the apex of the CM structure which covers the parachute system through reentry. ELS parachutes operate in a sequence of three steps. First, the two drogue chutes, which are a Fist ribbon type 13.7 feet in diameter, are mortar deployed at 25,000 feet plus one second. Next, the three pilot chutes, which are 10 feet in diameter ring slot types, are mortar deployed at 15,000 feet. The three main chutes, of a ring sail type, are 88.1 feet in diameter and are deployed by the pilot chutes. Velocity of the CM at impact should not exceed 30 feet per second.

Bombs, sea markers, a flashing light beacon, and radio devices, are provided as recovery aids. In addition to these, a survival kit for each man will be included which contains a life raft, water, de-salting kit, knife, flares, signal mirror, survival glasses, transceiver, first aid kit, and glucose.

Service Module (SM)

The Service Module, Figure 4-2, contains the Service Propulsion System plus selected equipment and stores which service the equipment and crew of the CM. The SM is unmanned and does not require crew access during flight. It remains with the CM throughout the flight until it is separated prior to reentry. Nominal dimensions and approximate weights of the SM are:

Length	14 feet(excluding nozzle extension)
Diameter	13 feet
Weight dry	8,000 pounds
Weight loaded	50,000 pounds

Main propulsion of the SM is provided by a single gimbaled engine with a nominal thrust of 21,900 pounds. It is ablative cooled. Propellants used are 50% UDMH - 50% N_2H_4 and N_2O_4. They are pressure fed to the combustion chamber. The SM reaction control system will be used to supply the acceleration necessary to force propellants to the bottom of the tanks for ignition of the main engine. A propellant utilization system is included which will be controlled by the crew members. The thrust chamber will be capable of gimbaling for thrust vector control in the pitch and yaw planes.

Propulsion for the RCS is provided by sixteen low thrust engines which are radiation cooled. Propellants are supplied by two sets of tankage and each set will supply eight thrust chambers. Positive expulsion devices are used to assure liquid flow in the free fall condition. The same propellant combination is used in the RCS and in the main propulsion system.

Guidance commands for the SM are developed by the guidance equipment located in the CM.

Electrical power for operation of SM and CM systems will be provided by a fuel cell system, located in the SM, which consists of three independent fuel cell modules. Two of the modules will be capable of supplying the normal power demand and one of the modules can be used to supply essential power loads in an emergency. These cells use hydrogen and oxygen and are nonregenerative. Each module will be composed of an assembly of single cells electrically connected in series. Nominal cell operating pressure and temperature will be approximately 60 psia and 273°C to 260°C respectively. Aqueous potassium hydroxide will be utilized as the electrolyte. The fuel cells will supply 28±3 volt d.c. power to operate the spacecraft d.c. system and to the three 400-cycle inverters to supply 115/200 volt, 3 phase, a.c. power.

Lunar Excursion Module (LEM)

The LEM will be used to carry two members of the crew and a scientific payload from the CSM in lunar orbit to the lunar surface and the astronauts with part of the scientific equipment and lunar samples back to the CSM. The LEM will also serve as a base for crew exploration of the Moon. Systems necessary to complete the lunar descent, touchdown, launch, rendezvous and docking with the CM, independent of the CM or Earth-based information, will be contained in the LEM. After transfer of the crew and scientific payload to the CM, the LEM will be left in lunar orbit and not returned to Earth.

During launch from Earth and the injection maneuver, the LEM will fit within the free volume of the Adapter and Instrument Unit.

Three propulsion systems are used in the LEM. A descent system provides the propulsion required to leave lunar orbit and perform a controlled descent to lunar touchdown. The descent stage contains an engine with a nominal thrust level of 10,500 pounds which is throttable down to 1,050 pounds of thrust. All propulsion systems in the LEM use 50% UDMH - 50% N_2H_4 and N_2O_4 for propellants. An ablative chamber design is used in the descent engine. An ascent engine with a nominal thrust of 3,500 pounds will be used which will also have an ablative chamber. An auxiliary propulsion system of sixteen thrust chambers on the LEM ascent stage will be used for both the descent and ascent configurations. These engines are identical to the ones used on the Service Module.

A guidance and navigation system will be used in the LEM which will permit it to operate independently of the CM and Earth-based stations. This system will be similar to the one to be used in the CM and will use interchangeable components wherever possible. Two major distinctions may be noted: The LEM will not have a sextant but will rely on a scanning telescope and the computer in the LEM will be smaller than the one used in the CM. The guidance equipment located in the LEM will normally be used only during the time the LEM is occupied by the crew to descend and return from the lunar surface.

A life support system, similar to that in the CM, will be used in the LEM. The system will be capable of maintaining a 3.5 psia atmosphere for 2 minutes should a single hole of 0.5 inch diameter or less be experienced.

Electrical power will be provided by hydrogen-oxygen fuel cells.

Potable water for the LEM crew will be transferred from the CM prior to separation. Food and first aid supplies will also be provided in the LEM.

Total loaded weight of the LEM, without the crew, will be approximately 27,000 pounds.

The LEM will be capable of approximately 45 hours' operation on the near-Earth side of the lunar surface during any phase of the lunar day-night cycle.

The LEM structure will be equipped with four landing legs to absorb landing shock when the LEM contacts the lunar surface. At the time of impact on the lunar surface velocity of the LEM should not exceed 10 feet per second vertically and 5 feet per second horizontally. The LEM will be capable of landing on a surface with a mean slope of up to 15°. Lunar lift-off will be possible with the descent stage, which is left on the surface tilted up to 30°.

Launch Escape System (LES)

The LES provides the propulsion necessary to move the CM away from the launch vehicle should there be a need to abort the flight during early stages. Jettisoning of the LES will occur soon after second stage ignition.

Propulsion in the LES is provided by three solid propellant rocket motors. A 155,000 pound thrust motor provides the main escape propulsion. During the period the main escape motor is pulling the CM up from the launch vehicle another solid motor burns to pitch the module over and thereby provide horizontal range. After the escape motors have burned or when the LES is jettisoned after second stage ignition, a jettison motor operates to remove the LES from the CM.

The weight of the LES is approximately 6,600 pounds. The length is approximately 29 feet.

Spacecraft Adapter

The primary purposes of the Adapter will be to mate the spacecraft to the launch vehicle, to provide an aerodynamic shield over the LEM, and to support the LEM from launch through transpositioning. The top half of the Adapter will be jettisoned prior to transpositioning. The lower half will be separated from the LEM when the S-IVB/IU is separated from the spacecraft.

The Adapter will be shaped like a truncated cone approximately 28 feet in height. Approximate weight of the Adapter will be 3,250 pounds.

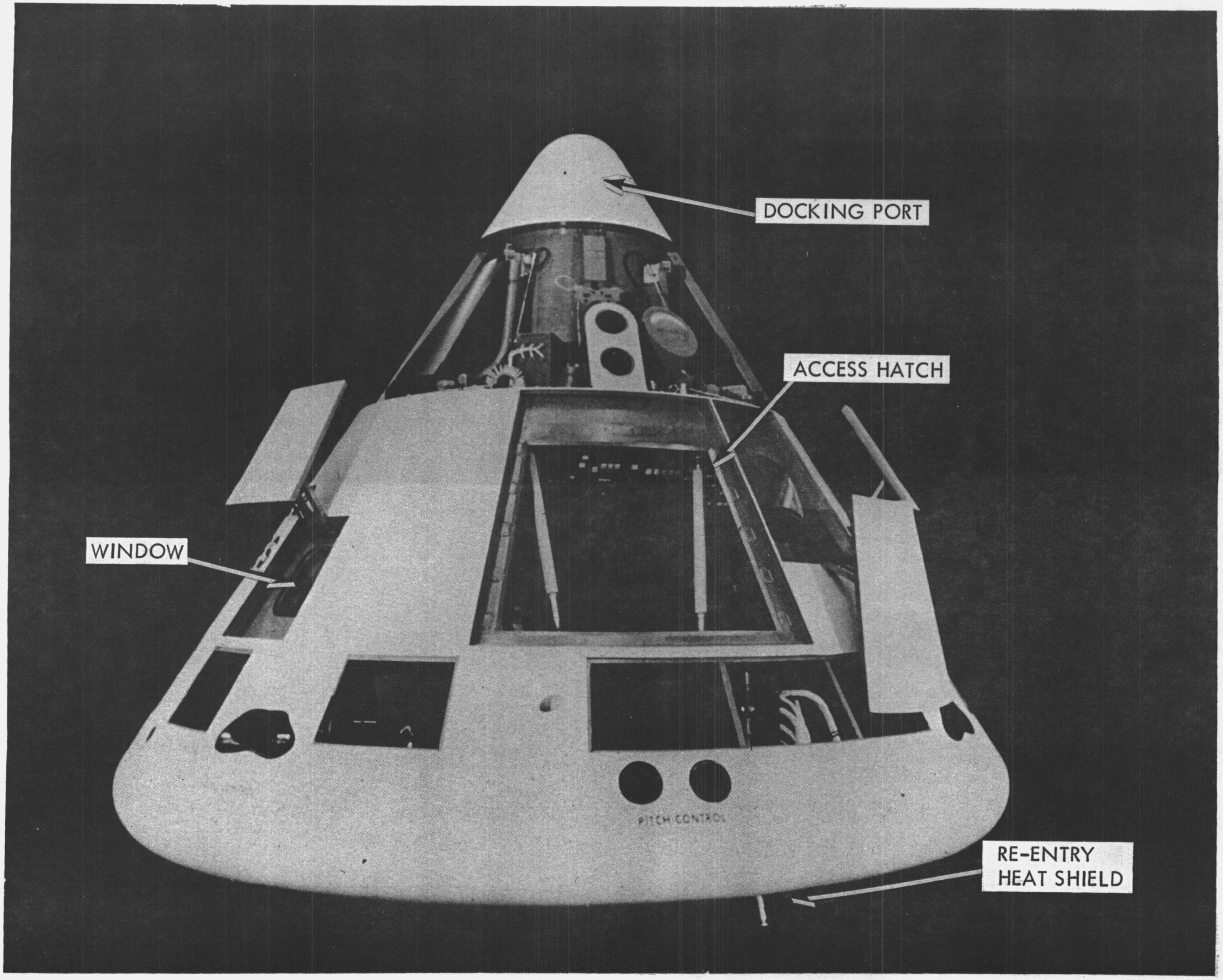

FIGURE 4-1 APOLLO COMMAND MODULE

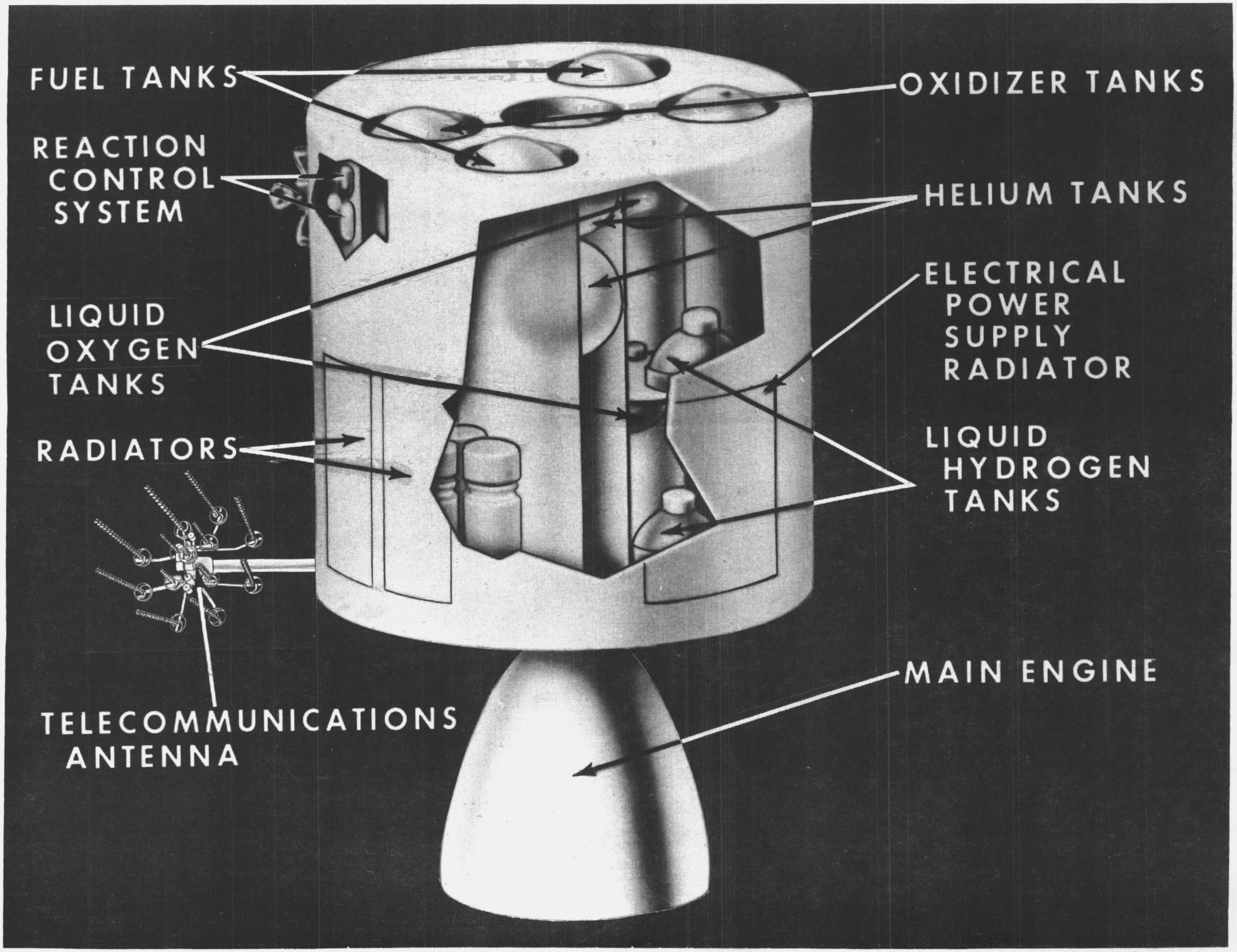

FIGURE 4-2 APOLLO SERVICE MODULE

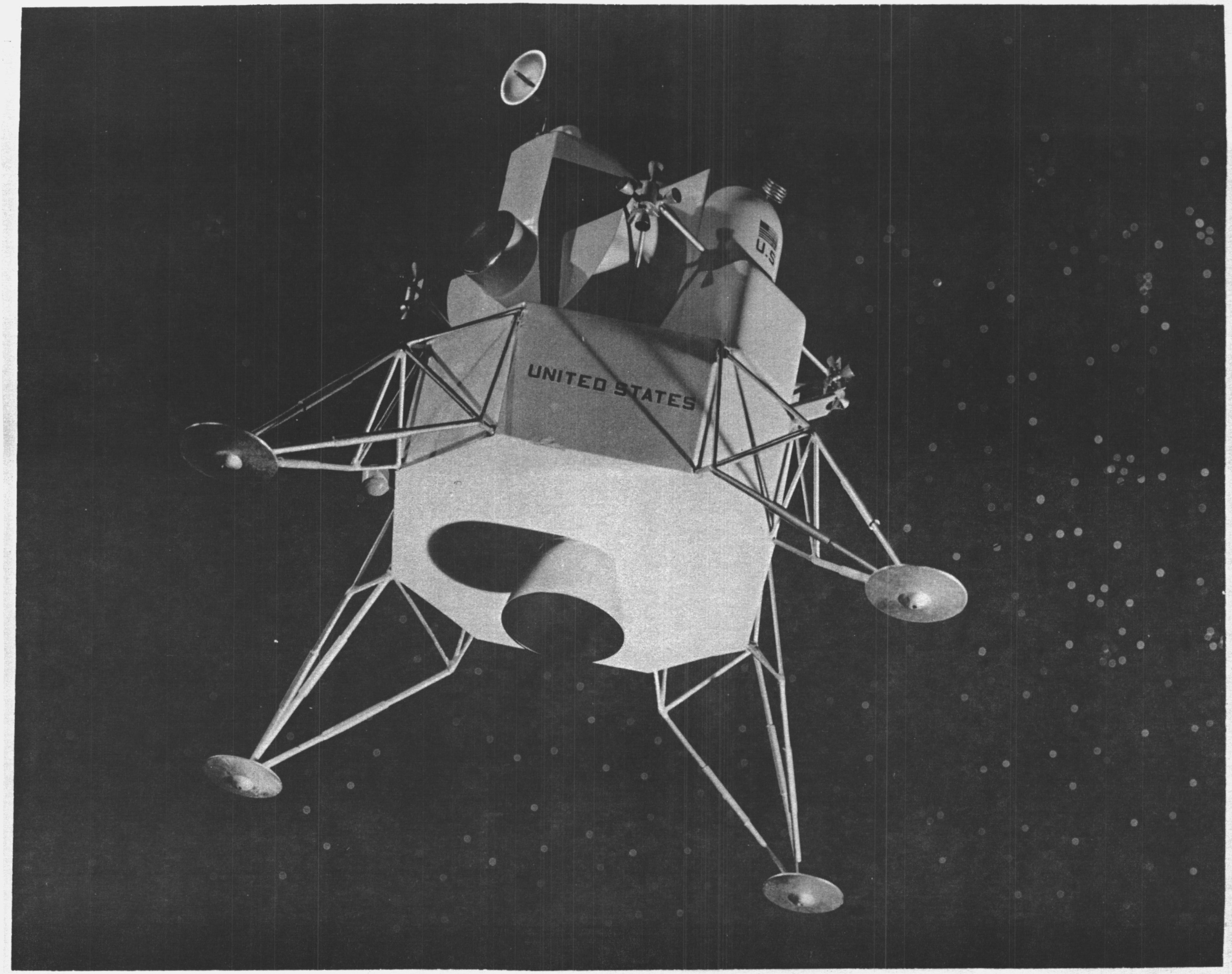

FIGURE 4-3 LUNAR EXCURSION MODULE

5. APOLLO SPACE SUIT ASSEMBLY

Space suits will be provided to each crew member. The design of the suit will permit its use in both the LEM and the CM and on the lunar surface. The space suit will be of anthropomorphic design and will permit donning, without assistance, in five minutes.

Normal design pressure for the suit is 3.5 psia. A 100% oxygen atmosphere will be used to match that of the Apollo spacecraft. The space suit will consist of three garments, with two of these garments constructed with multiple layers.

An inner garment will be worn by the astronauts as their constant wear clothing. This garment will contain the biomedical sensors which will be used to monitor body functions. The pressure suit is worn over the constant wear garment and it will provide, besides the primary pressure suit, a gaseous oxygen ventilation system and a secondary pressure suit which will inflate automatically if the primary layer is punctured. This pressure suit is designed to give the wearer as much mobility as possible. A separate garment for wear over the pressure suit will be used for additional thermal insulation while the astronaut is on the lunar surface.

The pressure gloves and the helmet will be attached to the suit by means of adapter rings. The helmet will have a close fitting liner, with adjustable suspension pads around the interior, and an outer pressure shell. Included in the helmet will be the earphones and microphone of the communications system, and some components of the biomedical monitoring system.

A special lunar overshoe will be used to provide thermal insulation from the lunar surface which will also have adjustable foot pads that can be varied in length and width to function similar to a snowshoe if the lunar surface is soft and porous.

Portable life support will be supplied for use during extra-vehicular operation. These back packs will allow up to four hours of continuous separation from the LEM for each LEM crewman. Provisions will be made to permit the back pack to be recharged.

The major components of the back pack units will be an oxygen tank, a contaminant control cannister consisting of a lithium hydroxide element and an activated charcoal element, a battery operated fan, a battery operated eight channel communication unit, a rechargeable silver zinc battery supplying 28 volt power, a water separator, a water boiler, and gas flow regulators. A separate emergency oxygen supply for use with the space suits will also be provided.

6. ASSEMBLY AND LAUNCH FACILITIES

The Apollo Saturn V will be assembled and launched at the Merritt Island Launch Area (MILA) adjacent to Cape Kennedy. The preparation and launch facilities, which encompass Launch Complex 39 and the industrial facilities of Merritt Island, are being designed and constructed in accordance with a mobile concept of operation. This concept embodies the following basic operations:

1) Erection, checkout and mating of the space vehicle to a mobile Launcher-Umbilical Tower (LUT) within a Vertical Assembly Building (VAB).

2) Transfer of the assembled and checked-out LUT/space vehicle by means of a crawler-transporter to the launch pad.

3) Final servicing of the space vehicle at the launch pad and the arming of ordnance items from a mobile arming tower.

Figure 6-1 depicts the sequence of operations that will be followed at MILA using the following major facilities.

Vertical Assembly Building (VAB)

The 524 ft. tall VAB will be the tallest building south of the Washington monument; its enclosed volume exceeding that of the Pentagon. It will provide a protective and, where required, controlled environment for the final assembly and preparation of launch vehicle stages and for the vertical assembly and initial overall checkout of the space vehicle.

The low bay area of the VAB will contain eight stage cells equipped for preparation and checkout of the S-II and S-IVB stages prior to mating to the S-IC in the high bay area.

Initially, the high bay area of the VAB will contain four bays for checkout of S-IC stages and for the assembly and checkout of Apollo Saturn V vehicles. Assembly and checkout of the space vehicle will take place on a mobile Launcher-Umbilical Tower (LUT) within the VAB so that umbilical connections which are made at the time of assembly will remain in place until final disconnect at launch.

The VAB, designed for a 20-year operational life, will be capable of withstanding winds up to 125 miles per hour. It will be situated approximately 3 miles from the nearest launch pad in order to provide protection against hazardous conditions existing on the launch pad.

Launch Control Center (LCC)

Located adjacent to the VAB, the LCC will provide display, monitoring, and control equipment used for checkout of the space vehicle in the VAB and on the launch pad. Commencing with initial space vehicle preparation in the high bay area of the VAB, the LCC will be capable of providing central control and coordination of all launch area activities involved in the prelaunch, launch and in-flight mission support of the space vehicle.

The four-story LCC will have four firing rooms, one for each high bay of the VAB. Each firing room will contain an identical set of control and monitoring equipment so that launch of one vehicle and checkout of others may take place simultaneously. There will also be a computer room for each firing room, providing computer equipment to be used in the automatic checkout and launch systems.

Launcher-Umbilical Tower (LUT)

The LUT, upon which the space vehicle is assembled and transported will provide the base for actual launch of the space vehicle. Its launch platform is a two-story steel structure, 25 feet high, 160 feet long, and 135 feet wide. The umbilical tower extends 380 feet above the deck.

The LUT will provide a CM access arm through which the astronauts will board the space vehicle, eight umbilical service arms, three tail service masts, and four support hold-down arms. The arms and masts carry electrical, pneumatic and propellant lines to the space vehicle and will also provide a means for personnel access to the interstage areas of the vehicle. A digital computer aboard the LUT will be used in conjunction with the LCC equipment for automated checkout and countdown of the launch vehicle.

Crawler-Transporter

The crawler-transporter will be used to transfer the LUT and unfueled space vehicle between the VAB and the launch pad, and to transfer the arming tower between its regular parked position and the launch pad as shown in Figure 6-2.

The 5,500,000 pound crawler-transporter will be capable of moving the LUT/space vehicle (12,000,000 pound maximum) at a speed of one mph on level grade and one-half mph on the five percent grade to the launch pad. It will have a mean turning radius of 500 ft. and will be capable of maintaining the LUT platform level within ten minutes of arc.

Arming Tower

By means of annular work platforms, the arming tower provides access to the space vehicle on the launch pad for the arming of ordnance items and for final servicing of the vehicle. It is moved to the launch pad and positioned by the crawler-transporter. The 7,500,000 pound arming tower is 130 ft. square at its base and rises 391 ft. above its base platform. It remains in position at the launch pad until about T-7 hours before being transported back to its launch-parked area situated approximately 8,000 feet from the nearest launch pad.

Launch Pad Area

Two launch pads are presently planned for construction at Launch Complex 39. A pad separation distance of 8,730 feet will allow operations on these pads to be independent of each other. However, it will be necessary to clear the adjacent pads of personnel during actual launch.

The launch pad areas are designed to provide final servicing, such as propellant loading of the space vehicle, prior to launch. The propellant storage facilities at each launch pad will include an 880,000 gallon tank for liquid oxygen located some 1,450 feet from each launch pad. RP-1, the S-IC stage fuel, is stored in three 87,000 gallon tanks located on the opposite side of the launch pad from the liquid oxygen tanks. Holding ponds, capable of holding the entire fuel contents of the S-IC, will be used to trap any RP-1 spilled from the vehicle. The RP-1 will be held in the ponds and skimmed for disposal. A 650,000 gallon liquid hydrogen tank is located in the same general area as the RP-1 tanks. Pressure of 75 PSIG is maintained in the vacuum-jacketed tank during fueling operations to accomplish transfer of the liquid hydrogen to the S-II and S-IVB stages. A burn pond will provide safe disposal of hydrogen boiloff from the storage tank and vehicle by burning it in the atmosphere after it has bubbled through water. Gaseous nitrogen and helium are stored underground in vessels near the launch pad.

Operations and Checkout Facilities (O & C)

Included in the spacecraft testing performed at the MILA Industrial Area will be a sequence of static firing tests, the only ones conducted on the completed modules after their manufacture. Systems tests of the spacecraft will be conducted in the O & C Building prior to delivery of the spacecraft as a combined unit to the VAB for mating to the launch vehicle.

Central Instrumentation Facility (CIF)

Instrumentation equipment and supporting activities which can be centrally located to serve Complex 39 as well as existing NASA complexes at Cape Kennedy will be located at the CIF in the MILA Industrial Area. During pre-flight tests, the CIF will be used to check space vehicle transmission for adherence to prescribed RF tolerances in order to insure compatibility between the vehicle and the manned space flight network. During launch and Earth orbit, it is anticipated that the CIF will function as a near-earth site of the manned space flight network. It will have the capability for real time data reduction and analysis of tracking, telemetry and television data for presentation to the LCC and to the IMCC.

Countdown

Fueling of the vehicle will commence with loading of the RP-1 fuel (approximately 235,000 gallons) aboard the S-IC on L-1 day. Propellant loading of the Apollo spacecraft and loading of the S-IVB reaction control system hypergolics will take place prior to T-7 hours on launch day.

At T-7 hours, the arming tower will be removed from the launch pad and loading of cryogenic propellants will commence. Liquid oxygen loading of the launch vehicle is first and will be performed from top stage to bottom stage to minimize the effects of boiloff. The propellant tanks will be pre-cooled before filling. Liquid oxygen will be pumped at a flow rate of 1,000 gpm into the S-IVB. Loading will require 32 minutes, including 12 minutes for pre-cool. The flow rate into the S-II will be 5,000 gpm and fill-up time will be 25 minutes, including 6 minutes pre-cool. The flow rate into the S-IC will be 10,000 gpm and will require 40 minutes including 11 minutes pre-cool.

Liquid hydrogen loading will be initiated next and will require 30 minutes including 10 minutes pre-cool to load 72,860 gallons aboard the S-IVB tank at a flow rate of 3,000 gpm. The S-II tank will require 35 minutes, including 10 minutes pre-cool, to load 263,000 gallons at a flow rate of 10,000 gpm. The launch pad facilities will be capable of maintaining the vehicle in a standby condition for up to 12 hours after cryogenic loading.

At approximately T-4 hours after the propellants are loaded, the astronauts will enter the spacecraft from the umbilical tower. During the remainder of the countdown, the final systems checks will be conducted.

During thrust build-up of the S-IC engines, the operation of each of these engines will be automatically checked. Upon confirmation of thrust ok condition, the launch commit signal will be given to the holddown arms and lift-off will occur. The point of no return for the space vehicle is release of the holddown arms.

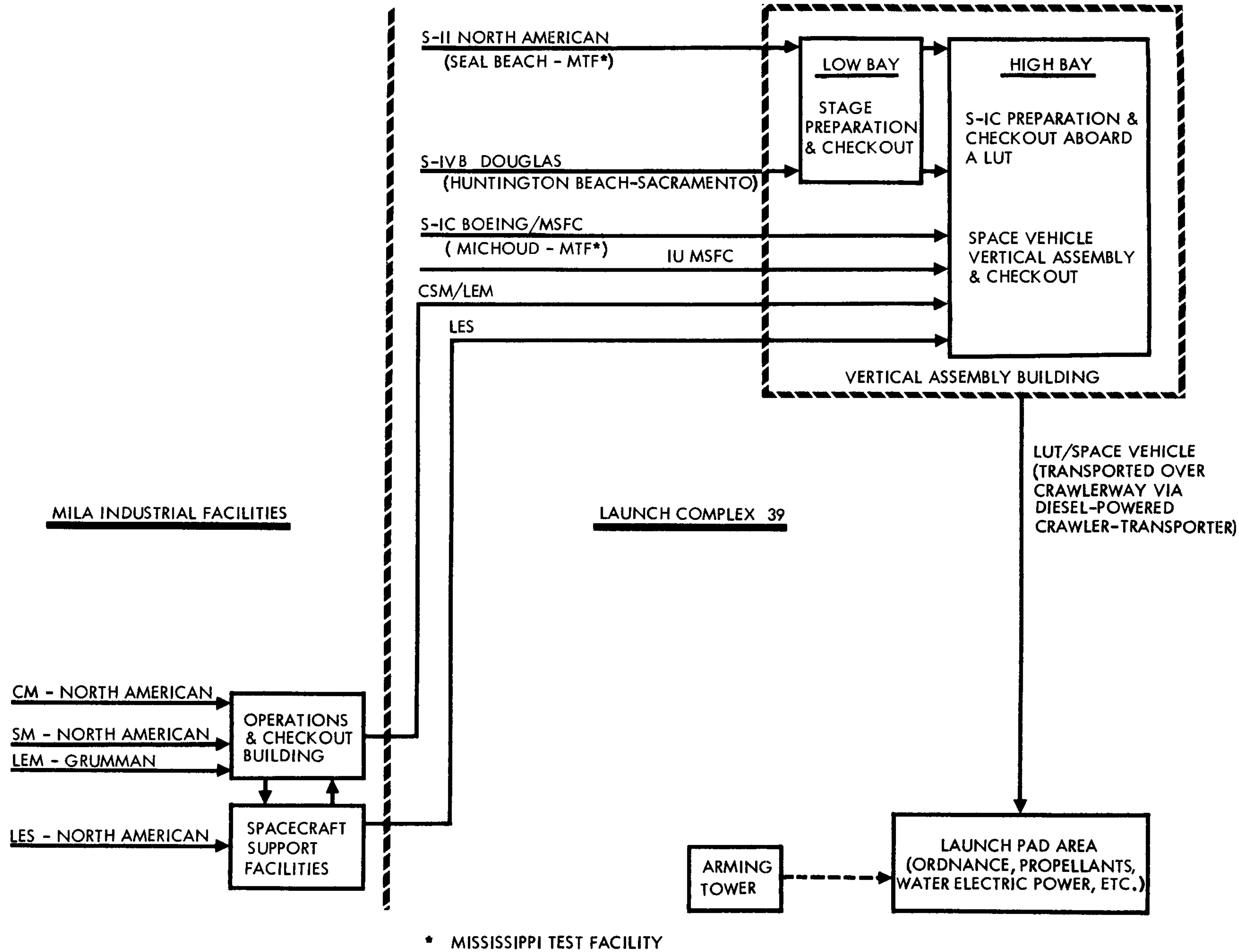

FIGURE 6-1 SEQUENCE OF LAUNCH PREPARATIONS AT MERRITT ISLAND LAUNCH AREA (MILA)

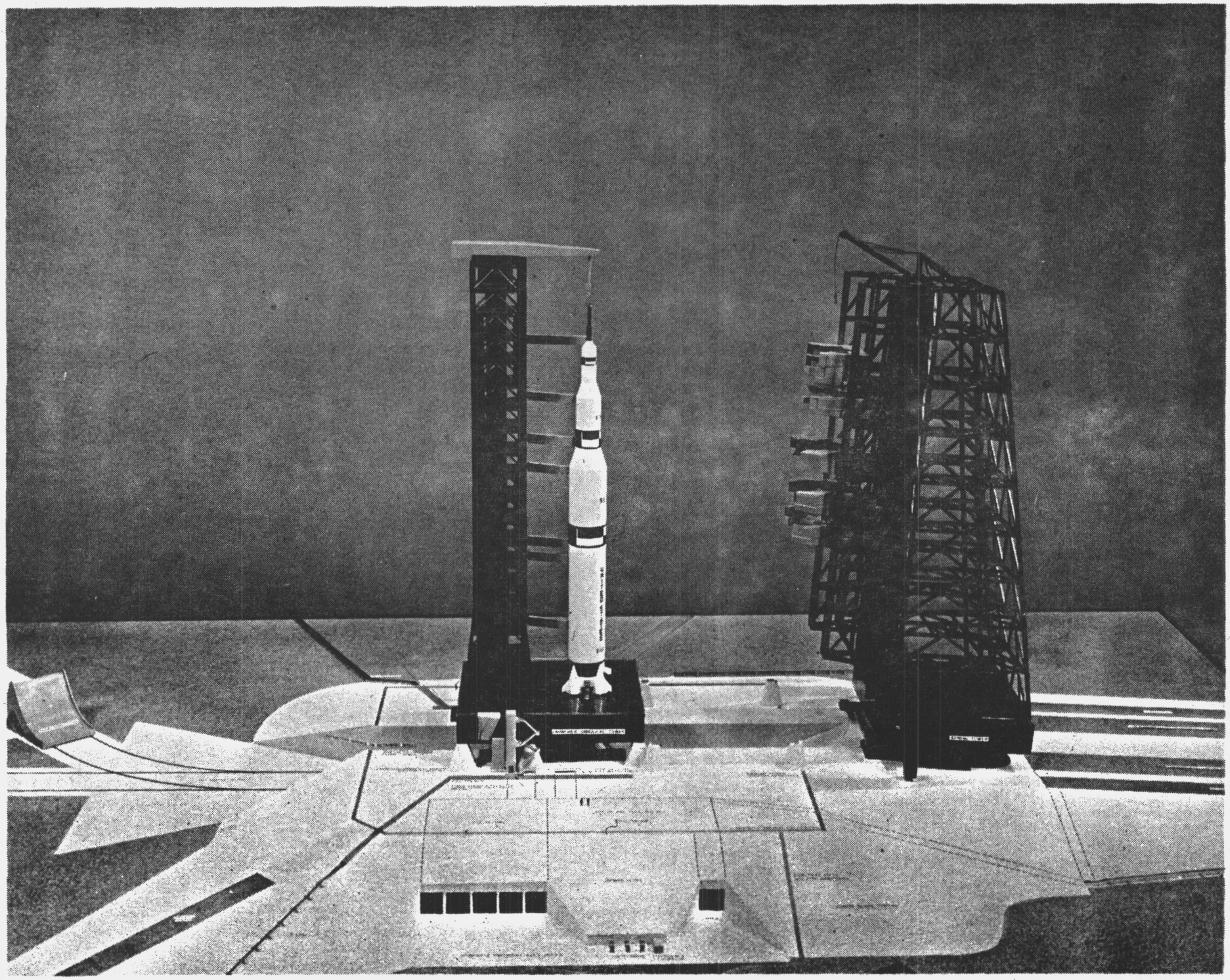

FIGURE 6-2 TRANSFER OF ARMING TOWER TO THE LAUNCH PAD

7. GROUND SUPPORT

Integrated Mission Control Center (IMCC)

Primary command and decision making responsibility for each mission will rest with the Integrated Mission Control Center (IMCC) at Houston. IMCC functions will include full mission control and technical management in the areas of vehicle systems, vehicle dynamics, life systems, flight crew activities, recovery support, and IMCC and network operation. Detailed mission control will take place within a Mission Operations Control Room (MOCR) - two of which are planned. A group of staff support rooms adjacent to the MOCR will provide detailed support to the MOCR in various specialty areas.

To exercise its command function, IMCC must be supplied with all data pertinent to the mission. These data will include status information on the launch vehicle, spacecraft, astronauts, computing and communication facilities, recovery forces, weather predictions and solar flare predictions. The critical element in obtaining this information is the Manned Space Flight Network (MSFN).

Under special conditions, the IMCC command responsibility may be delegated to the astronauts in the spacecraft or to some other earth-based site. For example, the Launch Control Center, which conducts the countdown of the launch vehicle, the spacecraft and the astronauts, will have command facilities to order an immediate abort, if necessary, during the launch period. Also, during the mission, if communications between the Earth and spacecraft are disrupted or if an emergency requiring immediate action occurs, the command function will be assumed by the crew commander.

Communication and Tracking Systems

Communication and tracking of the spacecraft will be provided by a network of stations situated around the Earth. In discussing communications and tracking, it is convenient to distinguish between stations which are primarily intended for tracking and communication when the spacecraft is close to the Earth (below about 10,000 miles) and those which would be used at greater distances including operations in the vicinity of the Moon.

Communication and tracking for deep space will be provided by equipment operating in S-band. The specific bands to be used (2100-2110 up and 2270-2290 megacycles down) are adjacent to that used by the Deep Space Instrumentation Facility (DSIF) implemented for the unmanned space programs. The Manned Space Flight Network (MSFN) deep space stations are now planned to be installed at Goldstone, California; Canberra, Australia; and Madrid, Spain. DSIF stations located at these same sites will be equipped to serve as on-line back-up for the MSFN stations. The geographical coverage provided by these three locations is shown in Figure 7-1. The MSFN deep space stations will employ 85 ft. dish antennas.

The deep space system will utilize a single RF carrier in the S-band to track and communicate with the spacecraft. The required functions will be performed by phase modulating the carrier with the sub-carriers associated with each function simultaneously. This is often referred to as a "unified S-band system". Separate main carriers will be used for the CSM and for the LEM. Tracking will provide an accurate determination of range, using a continuous pseudo-random noise code, and of range rate, using information derived from doppler measurements. This information will be combined with knowledge of the dynamics of the flight to determine the spacecraft trajectory in the deep space phases of the mission.

Communication functions for the deep space operations will include digital data transmission to and telemetry from the spacecraft, and two-way voice communication between the spacecraft and ground stations. Similar communication will be provided between the LEM and the ground when the former is separated from the CSM. In addition, the CSM and the LEM will be capable of transmitting television signals to the Earth using an FM mode of modulation.

Several alternatives are under consideration for communication and tracking when the spacecraft is below 10,000 miles. One alternative would use the techniques being implemented for the Gemini program. This includes radar tracking at C-band (5400 to 5900 megacycles), digital transmission from ground to spacecraft at UHF (400 to 450 megacycles), and two-way voice and telemetry at VHF (220 to 300 megacycles). This plan would make extensive use of the existing facilities with some modification of equipment to extend operating ranges.

Another alternative would use the unified S-band technique for near-earth as well as deep space communication. This would provide some saving in spacecraft weight at the expense of requiring more extensive additions to the existing MSFN.

The use of S-band for near-earth operation will not eliminate requirements for VHF voice equipment aboard the spacecraft. VHF is needed for efficient use of radio power for non-directive communication between the LEM, CSM, and astronauts exploring on the lunar surface. The CM will also carry HF radio equipment for two-way voice communication after the Earth landing.

Geographical coverage for near-earth communication should provide:

1) Continuous tracking and communication with the space vehicle from launch lift-off to about three minutes after the end of the first burn of the S-IVB;

2) Tracking and communication with the space vehicle for a period of at least three minutes, at least twice per orbit while the spacecraft and S-IVB are in Earth parking orbit;

3) Voice and telemetry reception from the spacecraft and telemetry reception from the S-IVB during the second burn of the S-IVB;

4) Tracking and communication with the space vehicle for a period of about ten minutes before transpositioning of the CSM/LEM.

Station locations meeting requirements (1), (2), and (4) are shown in Figure 7-2. These include a ship, labelled "insertion ship", in the Atlantic Ocean. To avoid limiting the mission opportunities to certain times of the month, it is desirable to have additional ships, shown located in the Indian Ocean in Figure 7-2, to track and communicate with the space vehicle during the translunar injection phase of the mission. It is expected that the exact location of these "injection ships" would be adjusted to provide the best coverage for specific missions.

The use of aircraft is being considered for the reception and recording of telemetry and voice from the spacecraft during the second burn of the S-IVB. These aircraft would be equipped to record telemetry and voice signals for later analysis. This data would probably not be sent to the IMCC in real time.

During reentry the spacecraft will be tracked by radar to determine the landing point. It is anticipated that this tracking will begin as soon as possible after the initial "black-out" resulting from ionization produced by the re-entering vehicle. Two reentry tracking ships are needed to cover a reentry which, at various times of the month, may occur at planned areas in the northern or southern hemisphere.

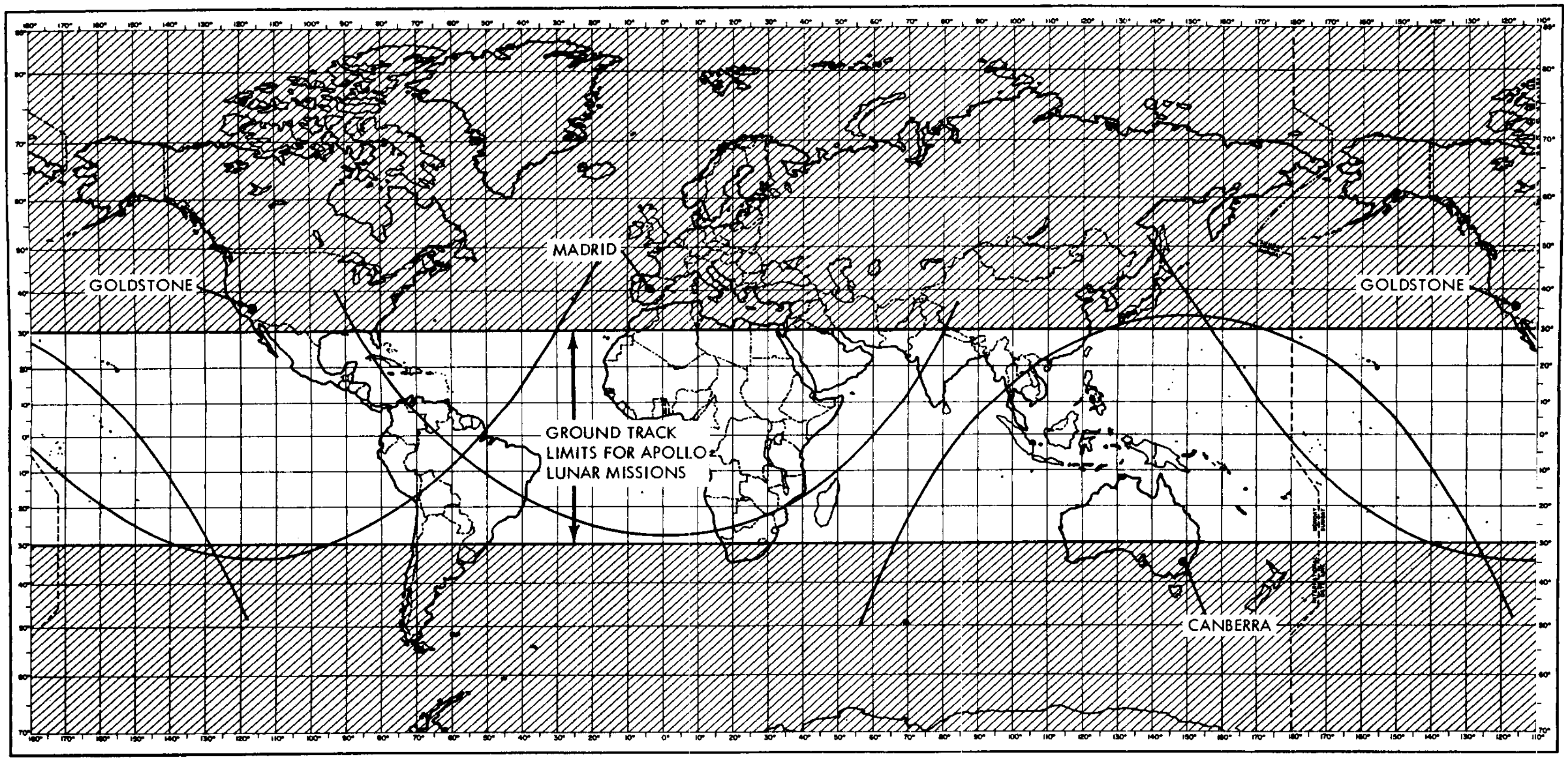

FIGURE 7-1 DEEP-SPACE COVERAGE

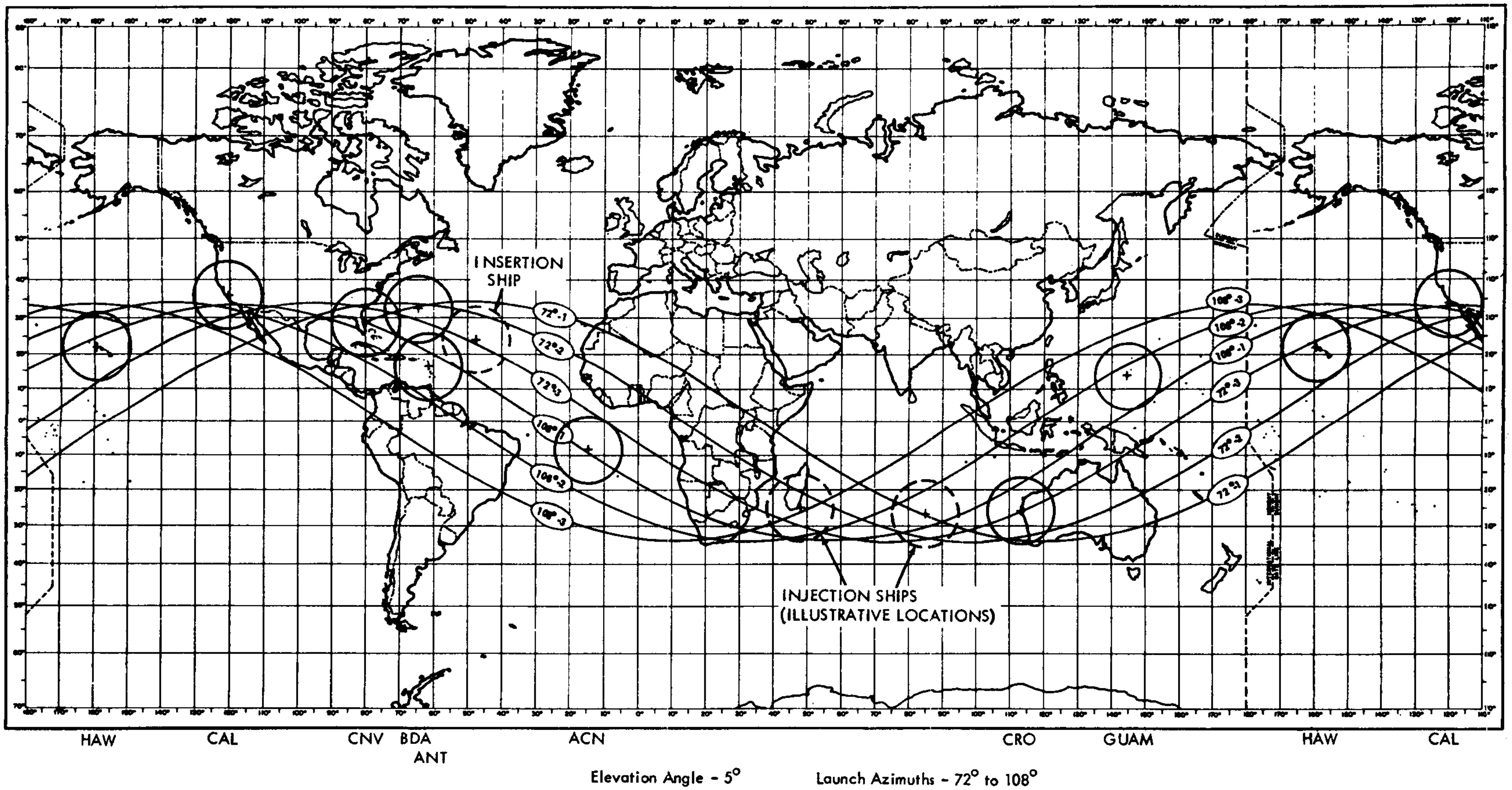

FIGURE 7-2 TRACKING COVERAGE OF FIRST THREE APOLLO PARKING ORBITS

8. FLIGHT TEST PROGRAM

Prior to the manned lunar landing flight, a launch vehicle and spacecraft flight test program will be undertaken to demonstrate hardware, evaluate crew and equipment performance in the space environment, and provide training for the astronauts and ground personnel.

In general, the flight test program for the spacecraft has been developed to be consistent with the availability of launch vehicles capable of carrying the required payloads.

Early flight tests to evaluate the performance of the Launch Escape System are to be made at White Sands Missile Range utilizing the Little Joe II launch vehicle. The payload for these flights will consist of the Launch Escape System and a boilerplate version of the Command Module.

Three Saturn class vehicles are used in the program. The first of these, the Saturn I, is a two-stage vehicle capable of placing approximately 22,000 pounds in low Earth orbit. Five successful flights of the first stage have been completed, the last of which, occurring on Jan. 29, 1964, carried an active second stage for the first time and orbited the world's heaviest satellite to date. The following five flights in this series will be devoted to launch vehicle R&D tests, spacecraft structural tests, and micrometeoroid experiments.

Following the Saturn I launch vehicle flights, tests will begin using the Saturn IB vehicle. This launch vehicle has the capability for placing approximately 32,000 pounds in low Earth orbit. The first stage is the same as that used in the Saturn I program. The second stage (S-IVB) of the Saturn IB will be used essentially without modification as the third stage of the Saturn V vehicle. Insofar as possible, the complete Apollo lunar orbit configuration - CM, SM, and LEM - will be flown beginning with the initial Saturn IB flight. In this "all-up" approach to flight testing, launch vehicle stages and spacecraft modules will be tested when possible in their final configuration (except for propellant off-loading) on each Saturn IB flight, thereby providing for the early recognition and solution of unforeseen problems.

When sufficient Saturn IB flights have been completed to demonstrate that crew safety objectives can be met, manned flight will begin. While spacecraft fuel will be limited, these manned flights will provide valuable training for the astronauts and ground personnel and an evaluation of those systems which are critical to the lunar landing program.

In the Saturn V program, launch vehicle and spacecraft tests will again begin simultaneously. Major objectives of the flight test series include R&D tests of the three-stage Saturn V launch vehicle and tests of the spacecraft with full propulsion and during high-speed reentry into the atmosphere. This series culminates, of course, with the lunar mission.

9. RELATION OF APOLLO TO OTHER MANNED AND TO THE UNMANNED PROJECTS

The Manned Spacecraft Program

The ultimate objective of the development of manned spacecraft systems is to provide the capability for a broad program of manned space exploration which will achieve and maintain a position of pre-eminence for the United States. Project Apollo is a specific goal in acquiring this capability. Its success will depend heavily upon the contributions made by Project Mercury and Project Gemini.

The first U. S. manned spacecraft system, Project Mercury, which ended with the successful 34-hour flight of Major L. Gordon Cooper, has provided many first's in man's exploration of outer space. Some of the accomplishments include:

1) The design of a spacecraft to provide a habitable environment for man operating in and returning from the extremes of outer space.

2) The operation of a world-wide network of radio and radar stations linked to a control center to provide constant control over each mission.

3) A determination of the physiological effects of weightlessness for periods up to 34 hours.

4) A demonstration of man's ability to function as an integral part of a space exploration vehicle and to enhance the systems reliability by his observations and judgments.

Project Gemini is designed to bridge the gap between Project Mercury and Project Apollo. Project Gemini will place two men in Earth orbit to explore long duration flight and to develop the techniques of space rendezvous and docking. Other areas of investigation for Project Gemini will include spacecraft maneuvering in Earth orbit, life support of multi-man crews, extra vehicular activity of man in space, maneuvering during reentry, and improved techniques of recovery.

It is anticipated that much of the Gemini technology will be directly applicable to Apollo. For example, both the Gemini and Apollo spacecraft will make use of similar automated checkout techniques. Also, the Integrated Mission Control Center at Houston and almost the same network of ground stations will be used for both Project Gemini and Project Apollo.

The Unmanned Spacecraft Program

It is the policy of Project Apollo that no manned vehicle shall attempt landing on the lunar surface until certain information essential to system design confirmation has been obtained by measurement of the in-flight environment and the lunar surface environment at the proposed landing site. Specific areas of interest include a determination of the roughness and bearing strength of the lunar surface, a determination and prediction of possible levels of radiation to be expected from solar flares, and a prediction of the mass and velocity distributions of micrometeoroid particles and the probability of their contact with the space vehicle. Some of this information may be derived from the unmanned programs such as Ranger, Surveyor and Lunar Orbiter.

Ranger is intended to relay television pictures of the lunar surface prior to impact.

The Surveyor spacecraft is being developed to accomplish the first soft landings on the Moon. Typical of the data to be obtained by Surveyor are: high resolution television pictures of the terrain in the vicinity of the landing site and measurements of the lunar surface hardness, the seismic activity and the chemical and mineralogical composition of the Moon. Specifically, Surveyor will test and verify in combination with the Lunar Orbiter the suitability of at least one landing site for Apollo landings.

The Lunar Orbiter is designed to be launched by an Atlas Agena into close orbit about the Moon where it will serve as a lunar reconnaissance system. It will photograph carefully pre-chosen areas with a resolution approaching one meter.